AGRICULTURAL ENGINEERING

FEBRUARY • 1951

Design and Performance Characteristics of the Forage-Harvester Cutterhead *O. I. Berge*

The Resistance of Long and Chopped Hay to Air Flow *R. B. Davis, Jr., and V. H. Baker*

Results of Long-Time Performance of Some Clay Draintile *D. G. Miller and P. W. Manson*

Determining the Relative Wear Resistance of Metals *I. F. Reed and E. D. Gordon*

The Basic Behavior at Freezing and Thawing of Six Foods *J. E. Nicholas and J. S. Perry*

THE JOURNAL OF THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

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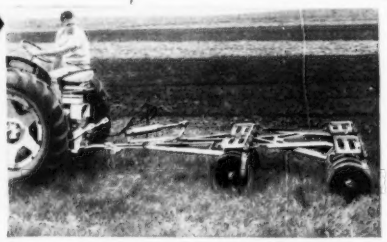
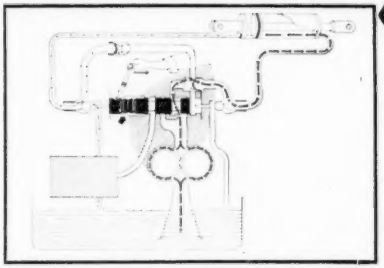
Here is a film created to bring hydraulic principles out of the realm of abstraction and make them a part of every-day living on the modern farm. Simple and clear enough for instruction at the secondary level, the treatment is technically sound — and so vivid that it fortifies understanding at higher levels, too. In fifteen fast-moving minutes it establishes a foundation of essential theory, shows construction and operation schematically, includes a wealth of applicational scenes. Arrange to see — or to show — this movie soon.

WHAT THEY DO

By action scenes with a dozen or more implements and machines, "Hydraulic Controls" teaches solid lessons in conservation farming, in saving labor, time, and other farming costs. Disk harrows are angled and de-angled on-the-go, sparing grass in waterways and on headlands. Both mounted and pull-behind implements are given attention. Function of the portable hydraulic cylinder is demonstrated, as is the interchangeability of ASAE standard cylinders.





HOW THEY WORK

Animated mechanical drawings show valves as they open and close; the pump pumps and oil flows; the hydraulic piston moves in or out at the will of the driver. Clear pictures and plain language make the workings of hydraulic controls easy to understand, hard to forget. The companion booklet of the same title can be studied at home and in class.

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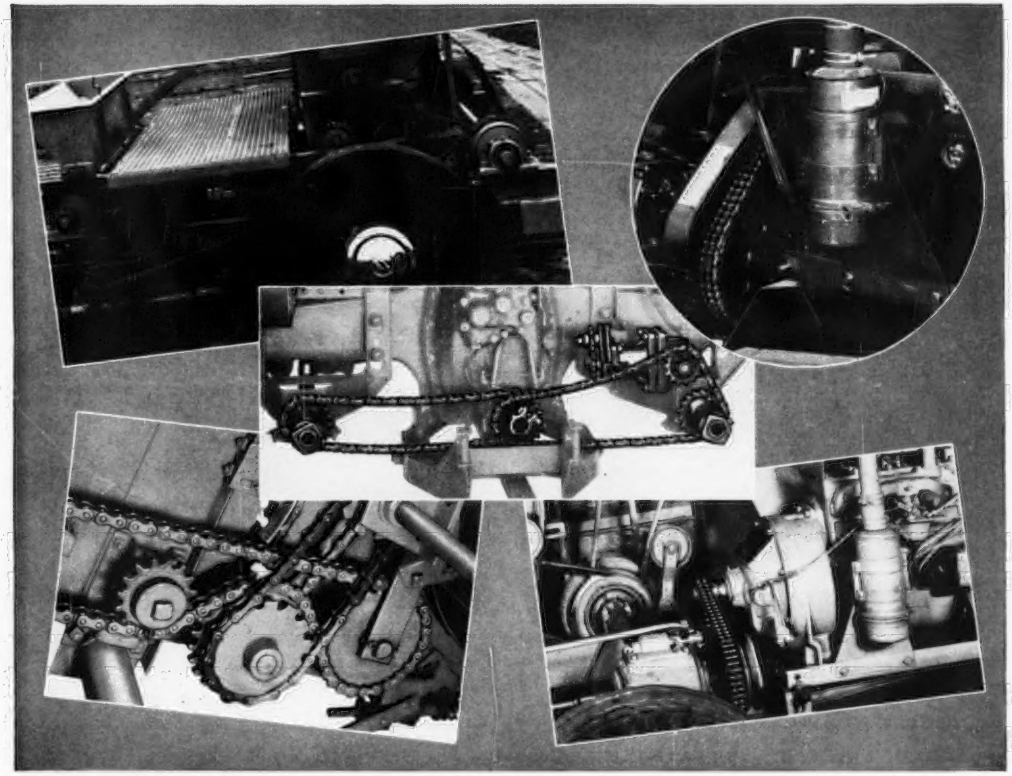

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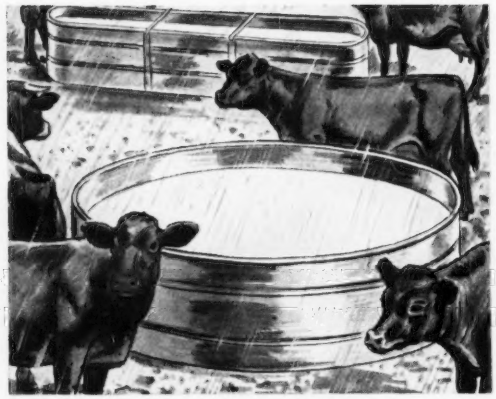

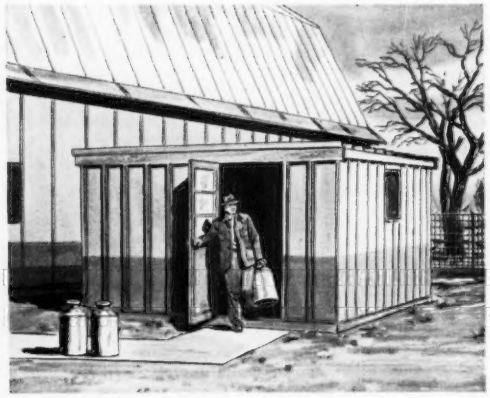

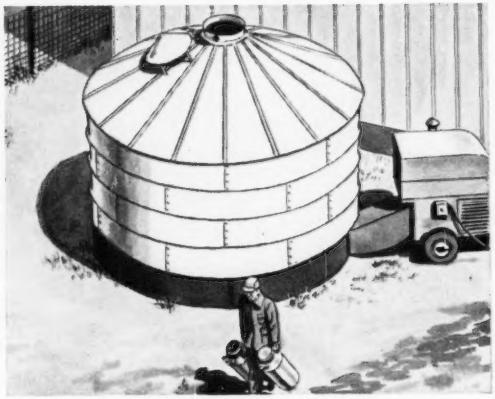

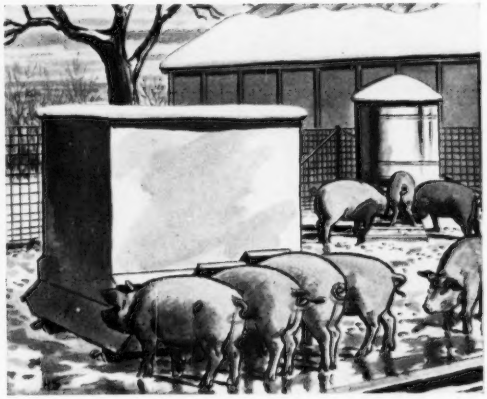

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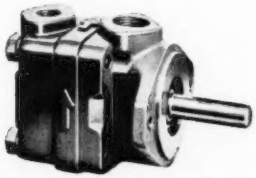
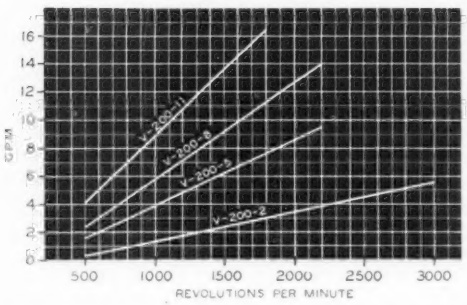


TYPICAL PERFORMANCE CURVE
AT 1000 PSI



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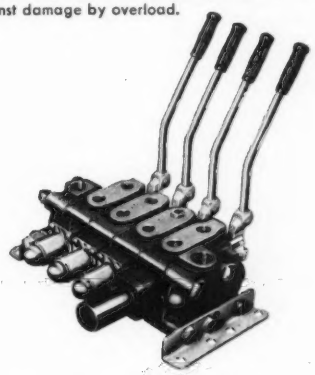

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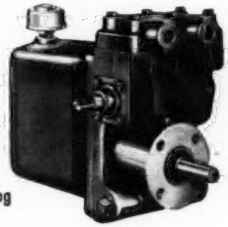

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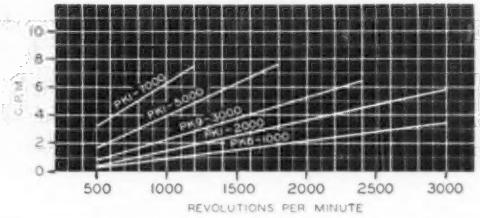

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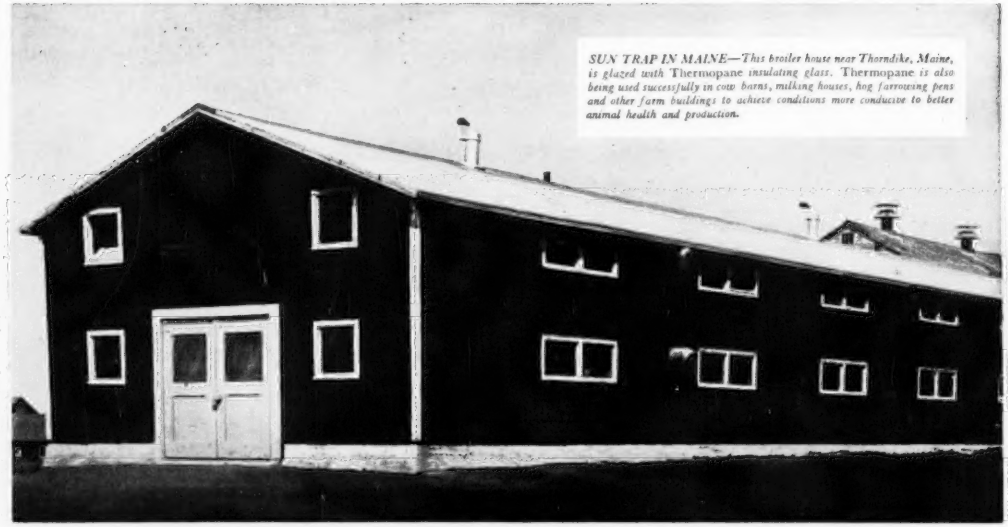
ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921



SUN TRAP IN MAINE—This broiler house near Thorndike, Maine, is glazed with Thermopane *insulating glass.* Thermopane *is also being used successfully in cow barns, milking houses, hog farrowing pens and other farm buildings to achieve conditions more conducive to better animal health and production.*

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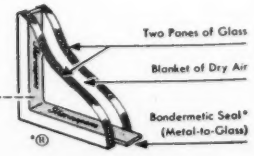

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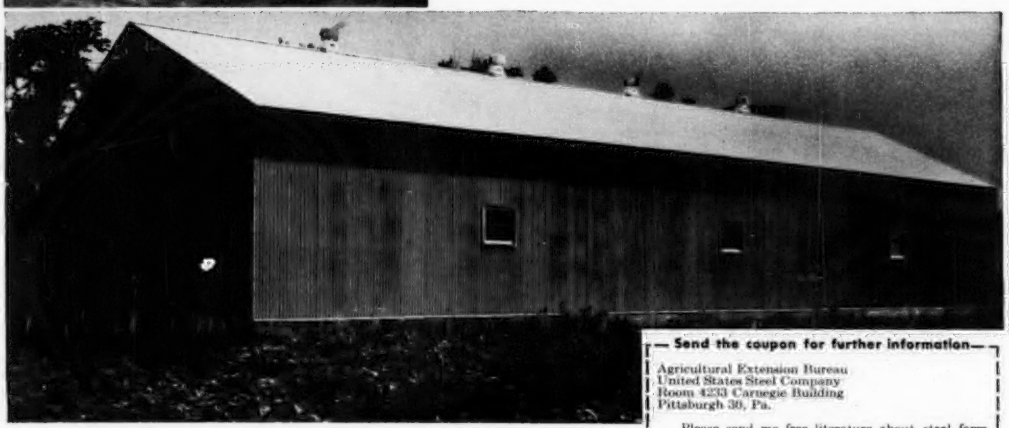

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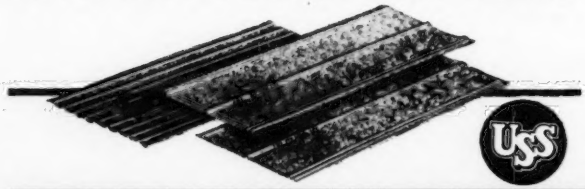

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When firms like these choose component parts, their engineers are skeptical and tough. That's why it's significant that Blood Brothers gets such an overwhelming vote of approval!

For upwards of 18 years so far, the engineers in some of these firms have specified Blood Brothers Universal Joints and Drive-Line Assemblies. Through the most brutal factory tests — through the roughest, toughest wear-and-tear of field use — they've proved their capacity to "take power around corners" . . . dependably.

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Agricultural Universal Joints

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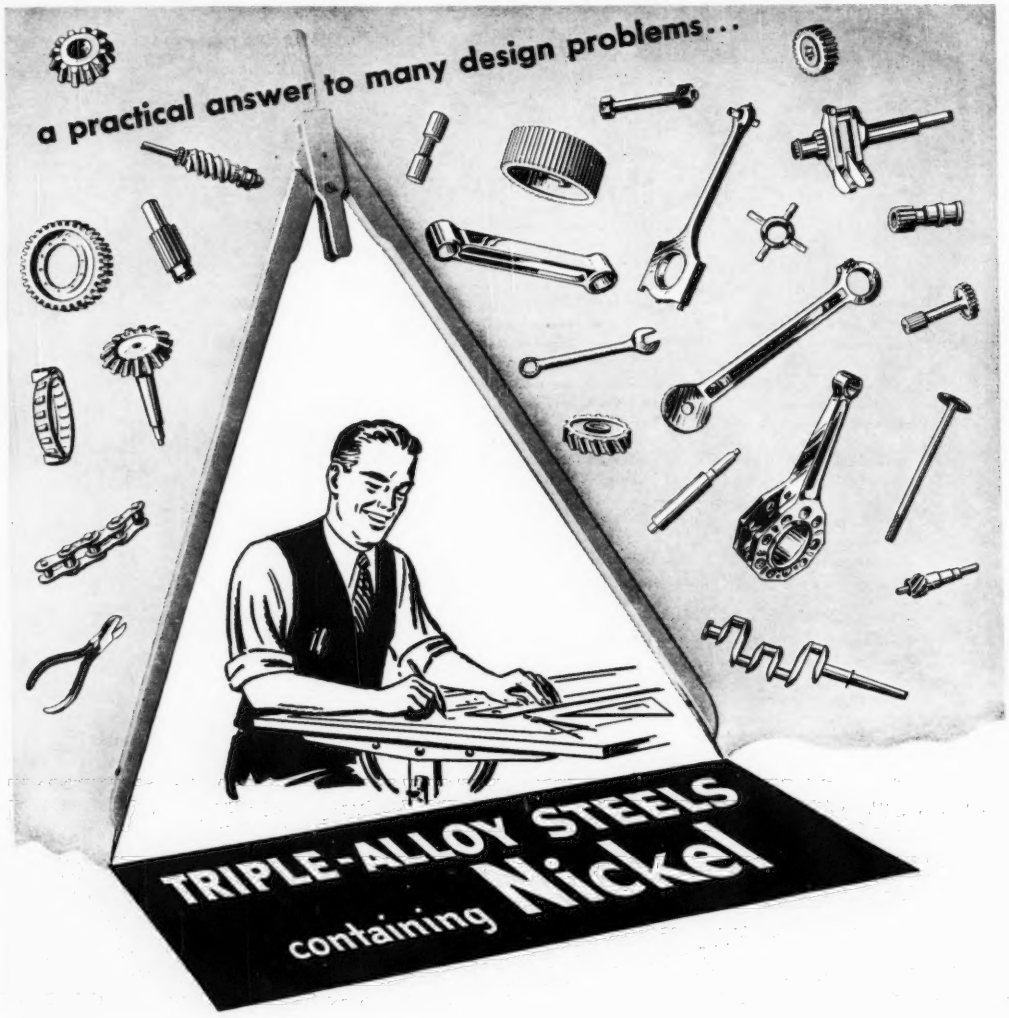
Division of Standard Steel Spring Company . . . Chicago Office: 122 S. Michigan



Triple-alloy steels containing nickel offer designers the following *triple* advantages:

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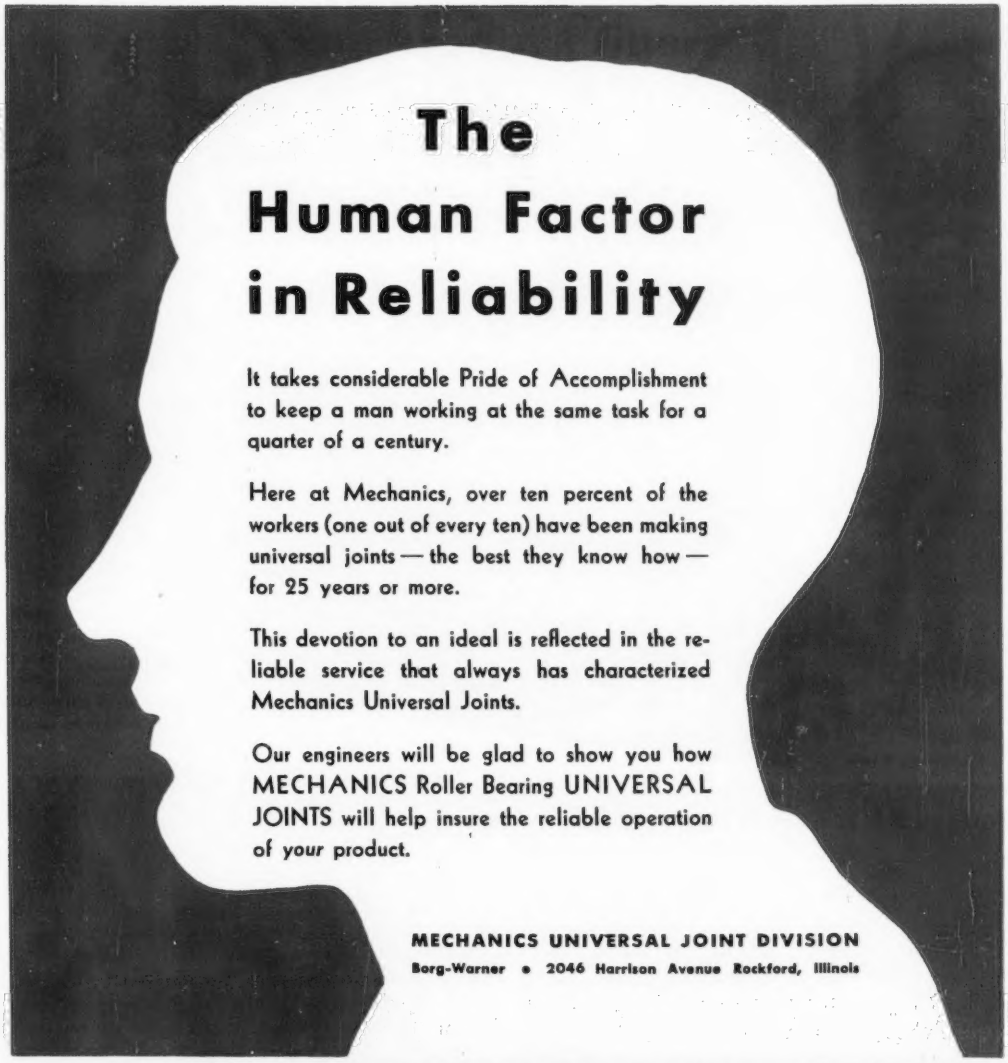

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It takes considerable Pride of Accomplishment to keep a man working at the same task for a quarter of a century.

Here at Mechanics, over ten percent of the workers (one out of every ten) have been making universal joints — the best they know how — for 25 years or more.

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For Tractors • Trucks and Farm Machines

GRAVELY TRACTOR — FAFNIR Ball Bearing Equipped

FAFNIR PILLOW BLOCKS offer the most capacity in the least space. Incorporate the famous Fafnir Wide Inner Ring Ball Bearing with Self-locking Collar.

FAFNIR RADIAL BALL BEARINGS available in single and double row designs, in duplex arrangements of matched pairs, and various arrangements of seals and shields.

Plow, harrow, spray, clear snow . . . there are twenty different jobs that can be done by the versatile little Gravely Tractor and its attachments. Such a variety of jobs puts a stiff burden on bearings and since they have much to do with the full productivity of Gravely's power equipment, they are subjected to rigid specifications.

Fafnir Ball Bearings are used in the transmission of the Gravely Tractor and throughout its many attachments. The snow blower illustrated shows two Fafnir Ball Bearing Pillow Blocks on the main shaft of the impeller that chews up snow.

Based on long and satisfactory experience, America's leading farm implement makers use many types of Fafnir Ball Bearings. Performance records aren't the only reason, however, for this choice. Of equal importance is the Fafnir attitude and aptitude . . . a way of looking at ball bearings from the users' point of view . . . an aptitude for doing just what they'd like done about their specific bearing problems gained from forty years of "ground floor" experience in not just one or two industries but in virtually all industries. The Fafnir Bearing Company, New Britain, Connecticut.

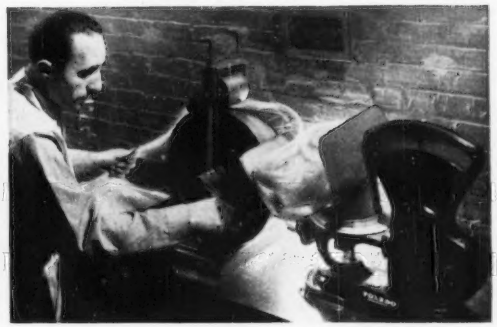
FAFNIR
BALL BEARINGS

MOST COMPLETE LINE IN AMERICA

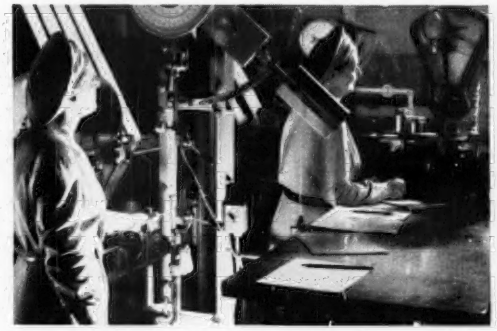
How tropical fibers become top-notch IH twine

A report to you about men and machines that help maintain International Harvester leadership

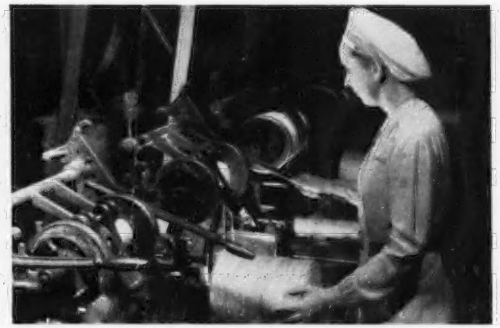
Only 30 henequen leaves in 1,000 will do for IH twine. To maintain such high standards, International Harvester operates its own plantation. Here's a native worker harvesting choice, mature leaves from which henequen fiber for twine is extracted. After drying and bleaching, our factories transform it into famous IH twine.



Sliver test double-checks baler twine after henequen fiber from Cuba and hemp from the Philippines have been scientifically blended. An IH inspector is shown weighing a sample of blended fibers before spinning. This is to make sure it will produce high quality twine that meets exacting IH standards for length, weight and strength.



Twine must pass the break test before it can wear the IH trade mark. Quality-minded inspectors multiply normal field strains many times with tensile strength testers—record the pull twine withstands before breaking. They also check uniformity and evenness of strand attained by combing the blended fibers eight times.



Workers autograph each ball of twine. Balls of IH twine look like peas in a pod, but each one carries the name of a balling machine operator. This is one of many inspection checks and countless safeguards that protect the quality of IH twine from plantation to packaged product. International Harvester Company, Chicago 1, Illinois.

INTERNATIONAL HARVESTER

International Harvester Builds McCormick Farm Equipment and Farmall Tractors . . .

Motor Trucks . . . Crawler Tractors and Power Units . . . Refrigerators and Freezers . . .

Home-Made Elevator

Loads corn on truck without hand labor

Peter Kautz (right) shows Texaco Man Howard Bell how easy it is to load feed with his portable elevator. Mr. Bell is the tank truck driver for Texaco Man D. C. McCornack of St. Charles, Illinois.

Mr. Kautz (right) keeps the bearings on his elevator rolling smoothly with Texaco Marfak lubricant; for Marfak sticks to bearings better and longer—resists jar-off, drip-out, wash-off or dry-up. It's the kind of lubricant farmers need for their machines, tractors, trucks and cars.

THE work of loading the truck to carry corn to the barn to feed 60 head of cattle was a time-consuming hand-labor job for Peter Kautz, well-known farmer of Route 2, West Chicago, Illinois, until he made the elevator shown at left.

Built at a cost of $10, plus the cost of a ½-hp. motor, and using parts of old machines, Mr. Kautz's elevator fills the truck in a few minutes, saving time and eliminating hand labor.

Mr. Kautz, like keen farmers from coast to coast, has found that *it pays to farm with Texaco Products.*

"This is the only motor oil you need," says Texaco Man W. F. Revere, Urbanna, Virginia, to Sam Bray, Farm Manager of the famous old Rosegill Farm. "Tests prove Custom-Made Havoline not only outperforms Premium motor oils but good heavy-duty oils, too."

One thing farmers need is dependable, neighborly service—and that's what they get from Texaco Men like Worth Bellamy (left), Goldendale, Washington. Worth is having a friendly chat with Mr. Ross Crafton who, with his son Royal, operates the 1130-acre R Hanging C Ranch. The Craftons are getting a tankful of Fire-Chief, the gasoline that packs extra power for low-cost operation.

FULL COLOR FILM

TEX
The Story of a Champion Calf

Shows How A Champ Is Raised—See it at your local Texaco Farm Meeting.

This exciting movie being shown at Texaco Farm Meetings across the country. Your Texaco Man can tell you when and where you can see it.

THE TEXAS COMPANY

TUNE IN . . . Metropolitan Opera broadcasts every Saturday afternoon. See newspaper for time and station.

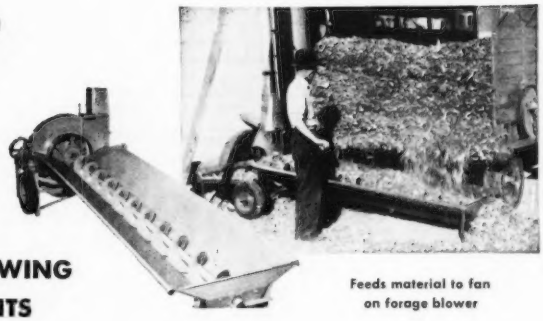
IT PAYS TO FARM WITH TEXACO PRODUCTS

DIVISION OFFICES: Atlanta 1, Ga.; Boston 17, Mass.; Buffalo 3, N. Y.; Butte, Mont.; Chicago 4, Ill.; Dallas 2, Tex.; Denver 1, Colo.; Houston 1, Tex.; Indianapolis 1, Ind.; Los Angeles 15, Calif.; Minneapolis 2, Minn.; New Orleans 6, La.; New York 17, N. Y.; Norfolk 1, Va.; Seattle 11, Wash.

Texaco Petroleum Products are Manufactured and Distributed in Canada by McColl-Frontenac Oil Company Limited.

LINK-BELT SCREW CONVEYOR,

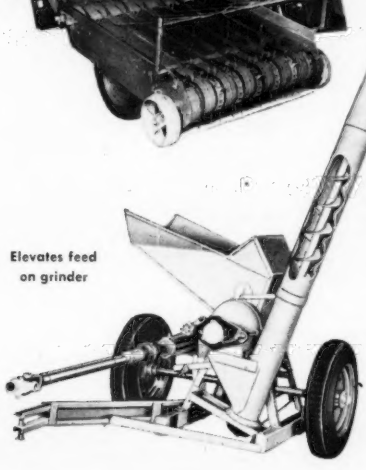
IMPORTANT ELEMENT ON A GROWING LIST OF AGRICULTURAL IMPLEMENTS



Feeds material to fan on forage blower

Gathers grain on combine

Conveys hay on baler



Elevates feed on grinder

The jobs Link-Belt Screw Conveyor can perform are becoming more and more numerous as engineers utilize its unique qualities . . . simplicity, ruggedness, uniform construction and availability in a wide range of gauges, pitches and diameters. Not only adapted for conventional purposes, these versatile elements are also finding increased usage for boring, elevating, mixing, spreading and feeding applications.

With years of experience and adequate manufacturing facilities, Link-Belt is especially well equipped to supply screw conveyor and flighting, either continuous rolled "Helicoid" or sectional, separately or welded to pipe or shafting as required.

Simple, compact, positive and durable, Link-Belt Screw Conveyors are well suited to many agricultural implement purposes. Link-Belt engineers will gladly cooperate with you in making effective use of screw conveyors in your new designs.

LINK-BELT COMPANY

Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Houston 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8, Johannesburg. Offices in Principal Cities. 12.214

Transfers cotton on harvester

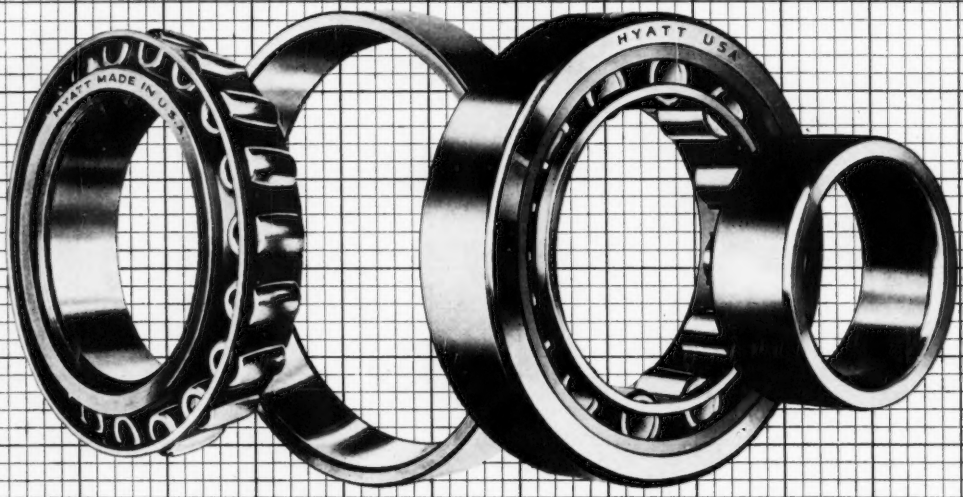
"Hyatt Equipped"

means longer life for farm machinery

From the earliest types of farm tractors to the streamlined models of today Hyatt Roller Bearings have been standard equipment in the best known makes of farm machinery.

Proof of performance is backed up by the fact that the leading manufacturers have built in Hyatts, year after year, to serve well and last longer.

These preferred roller bearings have gained the confidence of dealers because of freedom from failure. "Hyatt Equipped" is all the buyer needs to know about the quality of the bearings in any piece of farm machinery. Hyatt Bearings Division, General Motors Corporation, Harrison, N. J.



HYATT ROLLER BEARINGS

EDITORIAL

Partners in Progress

RECOGNITION of the importance of agricultural engineering to the farm equipment industry was included in the address of Theodore Johnson, president of the Farm Equipment Institute, in his presidential address to that body at its annual convention in October. On this subject he said, in part, "We should continue to develop new machines and improve those we now have. . . . We have not, in spite of all the progress that has been made in the past, in spite of all the engineering effort which has been put forth by the industry through the years and is being put forth at the present time, reached the point where we can say that there is nothing further ahead of us."

Specifically he mentioned opportunity to improve the industry's mechanical and parts service, and to work for the continuing development and application of farm equipment for soil and water conservation, pest control, safety, and improved farm practices.

It is good to see in the industry this further emphasis on the fact that agricultural engineering in the development and application of its products is an important influence on the capacity of the industry to be of genuine service to farmers. It is good to see among leaders of the industry, other than engineers, a recognition of the need and opportunity for continued work by agricultural engineers; a keen appreciation of the possibility of providing farmers with still better equipment and methods.

In return, we believe we can honestly say that practically all agricultural engineers, including those in public service as well as those in industry and private practice, appreciate the contribution of manufacturing and sales to the value of agricultural engineering work. That contribution is the quantity production and effective distribution of the equipment necessary in most cases to enable farmers to practice the improved methods suggested by the research and development work of agricultural engineers and scientists. Agricultural engineers and the farm equipment industry are truly close partners in serving agriculture.

Adapting Equipment to Users

OPERATORS or users are important factors among the use conditions which must be taken into account in developing a successful engineering design.

Designers of mechanical, structural, and electrical equipment for farm use, and even designers of land-surface profiles for soil and water control, have found by hard experience that this is the case.

A farmer's size, proportions, senses, responses, strength, dexterity, agility, endurance, resistances, general and specific knowledge, mental concentration or preoccupation, habits, training, and even unexplained preferences influence his willingness and capacity to use any specific design safely, effectively, and with satisfaction.

In the agricultural engineering field considerable know-how recognizing these human factors has been brought to design work more or less unconsciously in the farm background of designers. It has been supplemented by engineering contacts with farmers in field test work and by the accumulated experience of sales and service departments. In fact, designers have practically forgotten the day when their major concessions to the farm equipment operator were a contoured mild-steel seat and location of essential control levers somewhere within reach.

In agricultural engineering and in other fields of engineering application as well, this recognition of the user and his characteristics and limitations has remained largely a matter of fragmentary lore and has not been built into a well-organized branch of engineering knowledge. Progress in design showing increasing recognition of the user has been spasmodic. Refinement of adaptation to the operator has not kept pace with the internal refinement of devices and physical functions apart from the human factor.

A step toward correcting this situation has recently been taken by publication of the "Handbook of Human Engineering Data for Design Engineers." It was prepared by the Institute of Applied Experimental Psychology of Tufts College, for the Office of Naval Research.

We have not yet seen this handbook and do not know to what extent the data in it may apply to various types and items of agricultural equipment or to farm workers. It seems likely that it will include few if any direct references to the design of agricultural equipment, but that it may suggest a multitude of considerations which need attention in attempting to improve the adaptation of equipment to farm users. Additional thought along these lines should stimulate considerable progress in engineering toward making an equipment item and its operator a more effective working unit.

Machine Tools for the Farm

ONE of the major production lessons of World War II taught us that farm production in astronomical figures can not be taken for granted.

Reemphasis on that point, as a matter of important public information, has been provided in recent months by the Farm Equipment Institute.

In their words "Farm machinery and equipment are the 'machine tools' of the farmer and no less essential to him than machine tools are to industry."

In our thinking it follows that an important part of the work of agricultural engineers is the continuing improvement of farm machines and their application *as machine tools.*

Many agricultural engineers have undoubtedly thought of their work in these terms for a long time. For others who may not have done so, it may help to clarify objectives, and provide a standard by which to measure various possible approaches to specific problems.

Water for Manufacturing

SOME interesting sidelights on public understanding and appreciation of water problems have shown up in a recent report, entitled "Water in Industry."*

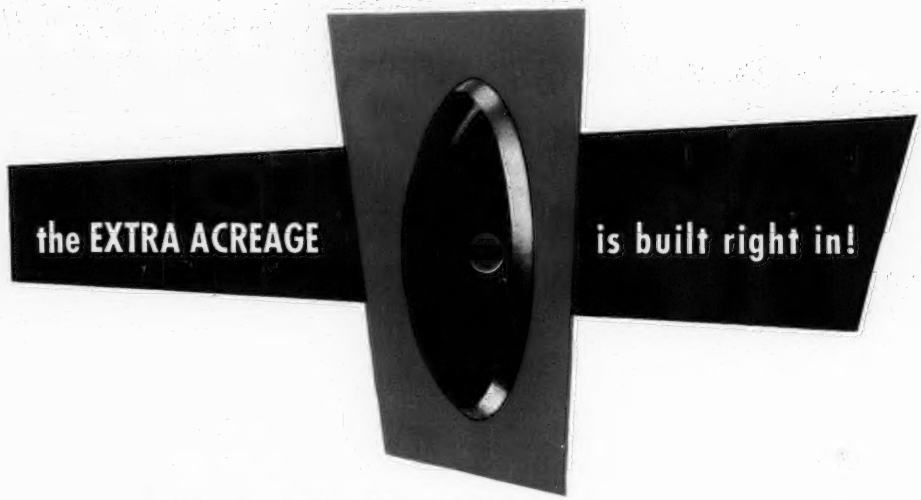
This report is based on a recent nationwide survey of representative manufacturers, largely on factual matters as to use of water by various types of industries. A few opinion questions were included in the survey, however, relating to local potentialities for expansion of water use, and to pollution.

We were particularly impressed by the indicated wide divergence of opinions on these matters. Representatives of individual areas looked at the water in their areas and failed to arrive at any clear-cut consensus of opinion.

Presumably the respondents answering the questionnaires for their respective companies were responsible executives most directly concerned with water supply. In many cases they may have been engineers.

As to potentialities for expansion of industrial water use in their own localities, the largest single group of replies was that in which the respondents frankly admitted that they did not know. As one extreme example, representatives of ten plants in the Dayton, Ohio, area replied, eight saying they did not know, and two saying that a few additional water-using plants in the area would be possible. Among representatives of 44 plants in the Buffalo, N. Y., area, 9 per cent felt that the water resources of the area were being used to capacity, and at the other extreme, *(Continued on page 124)*

*National Association of Manufacturers, 14 West 49th St., New York 20, N. Y., and Conservation Foundation, 30 East 40th St., New York 16, N. Y.



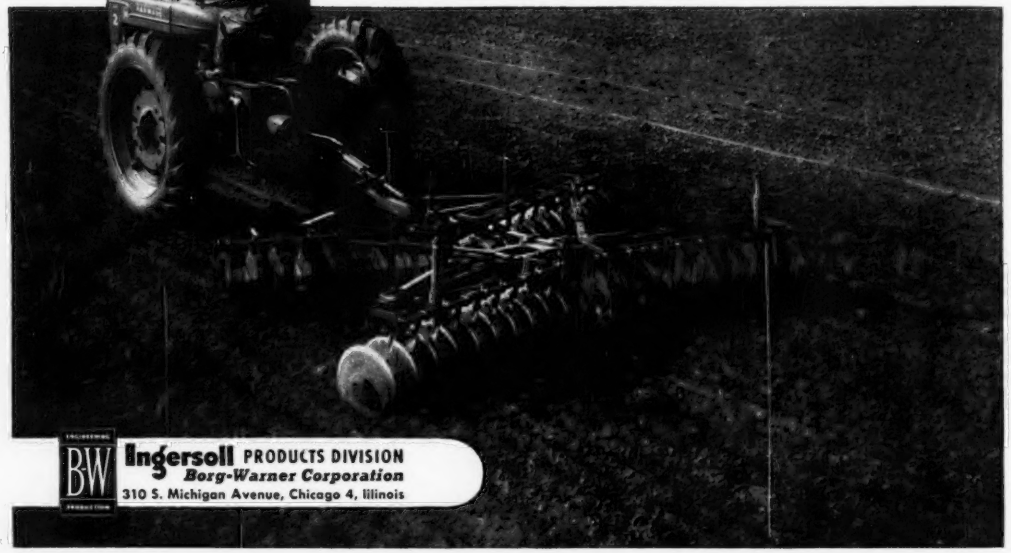
It's no secret that Ingersoll Discs stay on the job *acres longer* than ordinary discs. And it's no secret why! That *extra acreage* is built right in. You see—only *Ingersoll* Discs are made of TEM-CROSS Steel. Ingersoll's own remarkable steel that's cross-rolled to prevent split or curled edges . . . specially heat-treated for super-tough springiness. So Ingersoll Discs work better—longer.

Leading implement makers know it—and supply Ingersoll Discs as standard equipment on tillage tools. Farmers know it—and insist on Ingersoll for disc replacements. *Now you know it*—so specify Ingersoll-Galesburg for all requirements. Order Heat-Treated for normal work—Super-Alloy for rough and tough tillage conditions.

International Farmall Tractor with Disk Harrow equipped with Ingersoll Heat-Treated Discs.

Ingersoll HEAT TREATED **Discs**
Work Better—Longer

SPECIALISTS IN TILLAGE STEELS AND THE WORLD'S LARGEST MANUFACTURER OF DISCS



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Borg-Warner Corporation
310 S. Michigan Avenue, Chicago 4, Illinois

AGRICULTURAL ENGINEERING

VOL. 32 FEBRUARY, 1951 NO. 2

Design and Performance Characteristics of the Flywheel-Type Forage-Harvester Cutterhead

By Orrin I. Berge

MEMBER A.S.A.E.

THE forage-harvester method of handling forage crops is basically one of the most efficient of all present methods. This fact has been verified many times by agricultural economists* who have studied both the labor requirements and the over-all cost of harvesting the crop. In the job of harvesting corn or grass silage the machines now on the market produce a product which is generally without criticism. Only in the job of haymaking (where the hay is field-dried) is there occasion for criticism.

These criticisms are common, in some cases very outspoken, in others just a realization that all is not well. Farmers and feeding experts are saying that there is too much dust; the chopped hay often heats worse than long hay in the mow because the short lengths pack too tightly; the cattle often prefer long hay when given access to both long and chopped hay. They say too that the hay is hard to handle in feeding. These criticisms are valid. They have been verified in studies by feeding authorities. In one study at the Wisconsin College of Agriculture where cattle were allowed free access to long hay and various lengths of chopped hay from 0.25 to 1.8-in cut, the cattle ate more long hay than all the different lengths of chopped hay put together and indicated a distinct preference for the longer cuts as compared to the short cuts of chopped hay.

If this efficient labor-saving method is to be fully acceptable in meeting the farmers' needs, this defect must be remedied. The importance of the hay crop is reflected in the 73,624,000 acres devoted to hay in the United States as against 126,836,000 acres in small grains, 77,846,000 acres in corn for grain, and 4,065,000 acres in corn for silage.

These facts present a challenge to agricultural engineers to design a cutterhead for the forage harvester which will produce a product that the cow will like, and do this, if possible, without the need of a special machine nor excessive costs which would make it economically unfeasible for the farmer.

This is the background for the study which began at the University of Wisconsin in 1946 when the cooperation of the J. I. Case Company was secured in furnishing a machine in which modifications could be made.

Feeding trials had indicated that a longer cut was the key to the palatability problem; therefore efforts were directed to this end. It would seem at first glance that this is nothing more than a problem of increasing feed-table speed relative to cutterhead speed. This is correct up to the point where feeding interference occurs, but is further complicated by the fact that leaf and stem separation and leaf pulverization may occur after cutoff when the cut mass is abruptly accelerated and tossed about within the housing at high velocity.

Feeding experience seemed to indicate that at least a 3-in theoretical cut was desired and that this would be long enough if the hay was not further beaten and pulverized in its delivery from the housing.

Theoretical cut refers to the measured advance of the feed mechanism per knife passing the shear bar. The actual measured length of the cut material delivered will be the same as the theoretical only when the major axis of the cut material is parallel to feed table travel as with corn for silage. The actual average length of cut will always be greater than the theoretical for materials such as legume hay where the bulk of the material is more or less crosswise to the shear bar, provided that there is not excessive beating or pounding action within the cutterhead and blower housing which further pulverizes the material.

Fig. 1 presents diagrams of a number of different knife mountings which may be used in the cutterhead. It is known that the problem of securing a longer cut is determined largely by the question of feed interference. The following formulas show the relationship between knife angle, length of cut, spacing of knives, and proper distance between the flywheel shaft and the inner edge of the throat.

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1950, as a contribution of the Power and Machinery Division.

The author: ORRIN I. BERGE, extension agricultural engineer, University of Wisconsin, Madison.

AUTHOR'S NOTE: The results reported in this paper represent the combined efforts of F. W. Duffee, chairman of the agricultural engineering department, O. I. Berge and L. H. Hodges, University of Wisconsin, together with the cooperation of the J. I. Case Co.

*The Agricultural Situation, vol. 34, no. 10 (October, 1950).

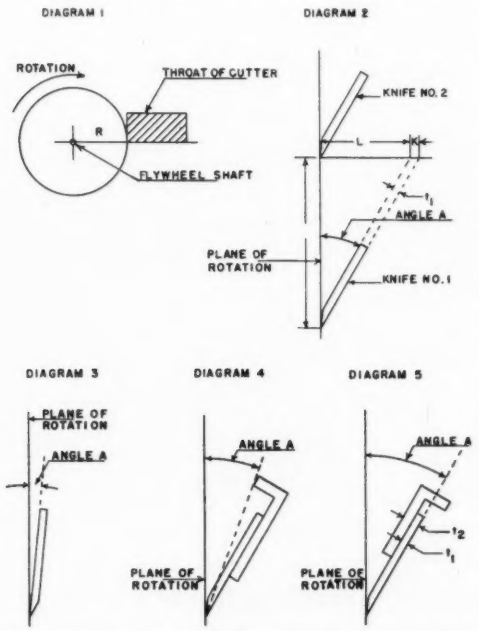


Fig. 1 Diagrams of a number of different knife mountings that may be used in the forage-harvesting cutterhead

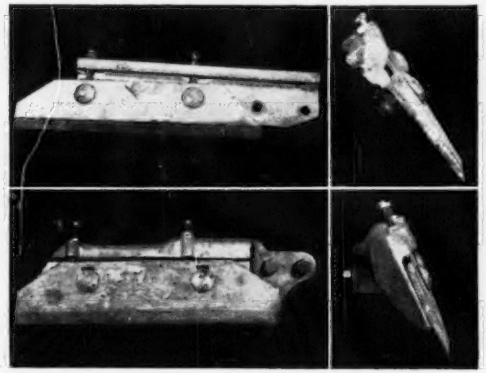


Fig. 2 *(Top, left)* Arm No. 1, side view • Fig. 3 *(Top, right)* Arm No. 1, end view • Fig. 4 *(Bottom, left)* Arm No. 2, side view • Fig. 5 *(Bottom, right)* Arm No. 2, end view

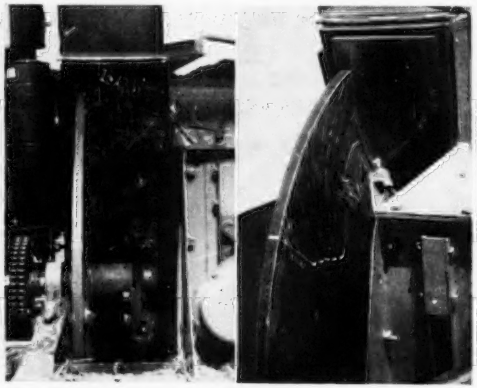


Fig. 6 *(Left)* Clogging of end supports, arm No. 3 • Fig. 7 *(Right)* Flow lines of material passing through cutterhead

Diagram 1 (Fig. 1) shows the dimension R to be determined. Diagram 2 illustrates the maximum length of cut L that can be secured without interference from the knife. Three types of knife mountings are illustrated in Diagram 3, 4, and 5. The following notations will apply:

L = Maximum length of cut in inches (Diagram 2)

R = Minimum radius to be determined (Diagram 1)

K = A dimension as shown in Diagram 2

Y = Circumferential distance between knives at radius R (Diagrams 1 and 2)

N = Number of knives

A = Angle between knife and plane of rotation.

The following formulas apply for Diagrams 2, 3, and 4:

$2\pi R$ = Circumference at radius R

NY = Circumference at radius R

$$Y = L/\tan A$$

$$NY = NL/\tan A = 2\pi R$$

$$R = NL/(2\pi \times \tan A)$$

The following formulas apply for Diagram 5, Fig. 1:

K (Diagram 2) $= t_z/\cos A$

Then K (Diagram 5) $= t_z/\cos A$

and $R = N\,(L + t_z/\cos A)/(2\pi \times \tan A)$

Example (Diagram 3, Fig. 1): Assume 2 knives; angle $A = 4$ deg, and length of cut 3 in.

Then $R = (2 \times 3)/(2 \times 3.1416 \times \tan 4)$
$= 13.67$ in.

Example (Diagram 4, Fig. 1): Assume 4 knives; angle $A = 20$ deg, and length of cut 3 in.

Then $R = (4 \times 3)/(2 \times 3.1416 \times \tan 20)$
$= 5.25$ in.

Example (Diagram 5, Fig. 1): Assume 4 knives; angle $A = 27$ deg; $t_z = \frac{3}{4}$ in, and length of cut 3 in.

Then $R = 4\,[3 + (0.75/\cos A)]/(2 \times 3.1416 \times \tan 27)$
$= 4.8$ in.

The example of Diagram 3, Fig. 1, shows that a two-knife machine, with a 4-deg knife angle and a knife mounting common in the flywheel machines, would require a minimum of 13.67 in from the center of the flywheel to the inner edge of the throat to avoid interference. Assuming a throat width of only 14 in, this would require an extremely large cutterhead of 56-in diameter or more. My reversing the knife so as to put the bevel to the shear bar and increasing angle A to 20 deg, Diagram 4, Fig. 1, there is no interference when $R = 5.25$ in with four knives. Assuming a 14-in throat width, a cutterhead of 42 in would be amply large. It appears from this that the most promising way of improving the operating characteristics of the flywheel-type cutterhead is to build a

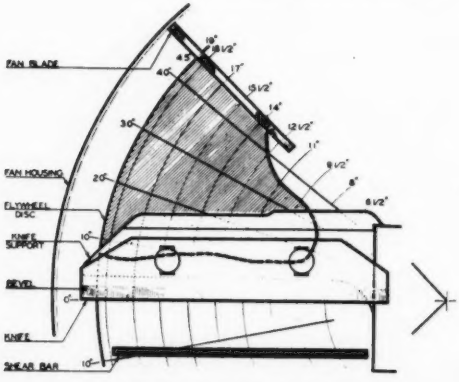


Fig. 8 Plotting of scoured area, short cut

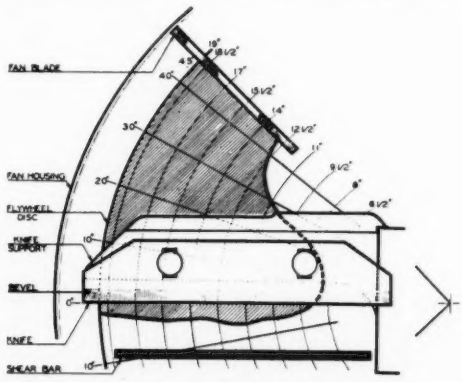


Fig. 9 Plotting of scoured area, long cut

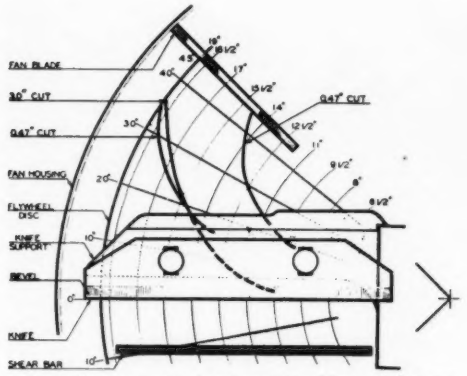


Fig. 10 Plotting of path of single particles of long and short cuts

machine with a knife angle similar to that shown in either Diagram 4 or 5, Fig. 1.

A cutterhead was built up using a knife mounting similar to that in Diagram 4. The arm support consisted of a very light steel section, extremely streamlined. This light arm (Figs. 2 and 3) performed well in test runs, being entirely free of feed interference. The cutterhead was operated for a time with the top half of the housing removed and minus the fan blades. The absence of throw, the light power requirement and the absence of leaf shattering in the product indicated the design was functionally correct. It was structurally weak, however, and, being extremely light in weight, difficulty with the drive belt developed when used in actual chopping trials.

Cast-steel arms (Figs. 4 and 5) were then designed and an external flywheel of 400 lb weight added. This gave very fine performance with the exception that (a) the external flywheel was not desirable for structural and safety reasons and (b) the cast-steel arms were expensive and a desirable substitute was sought.

In the next design the housing was widened from 6⅞ to 9 in and a ¾-in round steel plate 38 in in diameter added to the cutterhead inside of the housing. This disk, weighing approximately 240 lb, served as a support for the fan blades and served as a flywheel which was needed when operating at slow speeds.

Three different arm supports were built up and tested in the search for a substitute for the cast-steel arms which would be sufficiently rigid and yet give the same freedom to material movement. In each of these we attempted to place a support between the disk and peripheral end of the knife arm. The development of these supports was predicated on the idea that the knife blade and arm would pass *through* the cut material if sufficient room were available. A clearance space of 3⅛ in

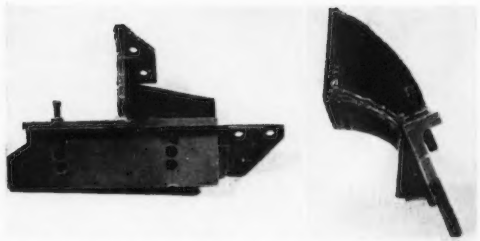


Fig. 11 *(Left)* Arm No. 4, side view • Fig. 12 *(Right)* Arm No. 4, end view

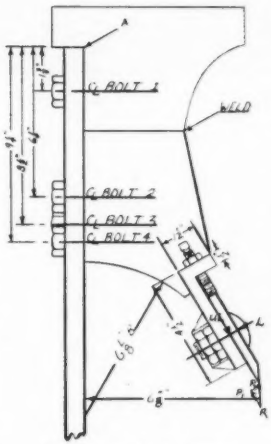


Fig. 13 Arm No. 4, diagram

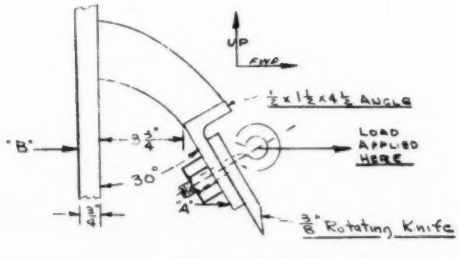
was provided between the knife arm and the disk for material to flow and yet after a very short period of operation, a clogging condition similar to that shown in Fig. 6 would develop. This indicated that material flow after cutoff was largely radial and that a support at that point would always cause clogging.

This clogging was not severe enough to stop the machine, but did increase the power required and further added to the beating action, thus reducing hay quality.

Flow Lines. The study of paint scouring was used in determining the path which material followed in the cutterhead. Hay striking the disk in its movement from the point where it is cutoff to the periphery of the wheel left a trace of its movement on the freshly painted surface of the disk. Fig. 7 is a photograph of these lines herein called "flow lines". Figs. 8 and 9 represent the results of a careful plotting of the scoured area with long cut (3 in) and short cut (0.47 in) material, respectively. Fig. 10 is the plotted trace of a single hay particle as observed for both long and short cuts.

These studies were made using the cast-steel arms which were supported only at the hub. By studying these lines we were able to determine possible positions for a support between the arm and the disk which would have a minimum amount of interference to material flow and be an efficient structural member.

The final support arm is shown in Figs. 11 and 12 with an



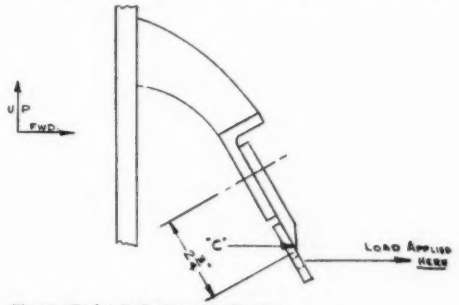


Fig. 14 *(Left)* Deflection of arm and disk • Fig. 15 *(Right)* Deflection of knife edge

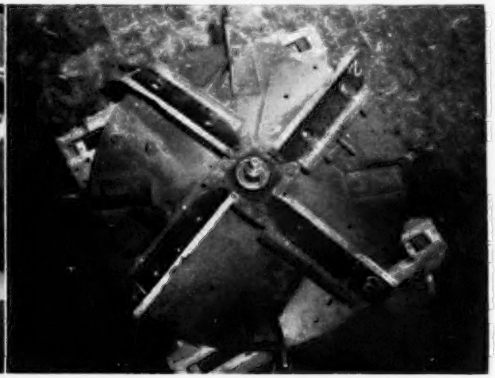


Fig. 16 *(Left)* Stone that entered the cutterhead • Fig. 17 *(Right)* Typical damage to knives and setscrews

end-view diagram in Fig. 13. The virtues of this support arm were that (a) it was equal to the cast-steel arm in functional performance, which includes freedom from interference to material flow and the final quality of chopped material; (b) it is cheaper to manufacture than the cast-steel arms, and (c) it can be reinforced to give any desired degree of rigidity without interference to material flow.

Deflection. The John Deere Company cooperated in making deflection tests. For these tests a dial indicator was mounted on an arm securely tied to the cutterhead drive sprocket. Loads were applied at the outer knife mounting bolt located approximately 17½ in from the axis of the cutterhead shaft. Dial indicator readings were taken at points A and B (Fig. 14) as close in line with the applied load as possible. The results are presented in Table 2:

TABLE 2

Load, lb	Reading no.	Deflections, in At A	At B
173	1	0.007	0.0025
173	2	0.0065	0.003
173	3	0.007	0.0025
	Average deflection	0.0068 in	0.0027 in

Deflection at the knife edge was then measured (Fig. 15). Results of these tests are given in Table 3.

TABLE 3

Load, lb	Reading no.	Deflections, in at point C
173	1	0.019
173	2	0.016
173	3	0.016
	Average deflection	0.017 in

This deflection is apparently well within the limits of the requirements since we have no evidence of the knife pulling into the sheer bar in cutting over 800 tons of grass silage and corn silage and 250 tons of hay and straw. The practice in making field adjustments has been to set the knife up until it strikes the shear bar and then back off just enough to clear. This will average about 0.005 in clearance.

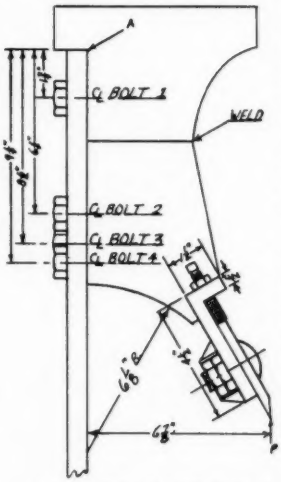


Fig. 18 Analysis of forces caused by striking stone

Stone Enters the Cutterhead. Really objective evidence of ruggedness of the design was obtained June 15, 1950, when a hard gray stone (Fig. 16) of igneous origin entered the cutterhead. The machine was cutting grass silage at 0.47-in theoretical cut with a cutterhead speed of 856 rpm when the stone weighing 8.5 lb and 17.25 in in circumference entered the cutterhead. Following was the extent of the damage: (a) The upper feed roll was nicked, (b) each knife was nicked so badly replacement was necessary, (c) two weld beads on knife supports were cracked, and (d) knife-adjusting setscrews failed in compression and had to be replaced.

Typical damage to the knife and setscrew is shown in Fig.

TABLE 1. SPECIFICATIONS OF THE VARIOUS MODELS OF CASE MACHINES

	Current production model	Experimental models			
		Early 1948	Late 1948	Early 1949	Late 1949
Width fan housing,in	6⅞	6⅞	6⅞	9	9
Flywheel location	Inside	None	Outside	Inside	Inside
Flywheel material	Steel	None	Cast iron	Steel	Steel
Flywheel size, in	Approx. 32 x ½	None	30¼ x 2 5/16	38 x ¾	38 x ¾
Flywheel weight, lb	Approx. 115	0	400	240	240
Blower pipe size	7 in square	7 in square	9 in square	9 in round	9 in round
Drive to cutterhead	Flat belt	Flat bed†	Double roller chain	Double roller chain	Double roller chain
Knife supports	Mounted on disk	Angle iron*	Angle-iron arms*	Cast-steel arms†	Angle-iron arms‡
Number knives for hay	2	2	2	2	2
Number fan blades for hay	2	2	2	2	2
Number knives for silage	4	4	4	4	4
Number fan blades for silage	4	4	4	4	4

Both experimental models equipped with Wisconsin Model VP4 air-cooled engines rated at about 30 hp maximum.
*Angle-iron arms supported at hub only. †Cast-steel arms supported at the hub only. ‡Angle-iron arms supported at middle as well as at hub.

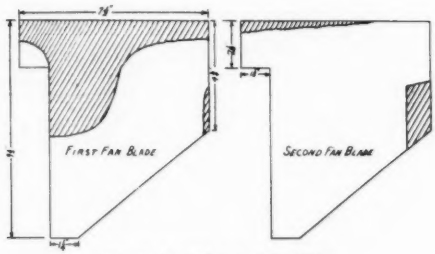


Fig. 19 Scoured area of fan blades

17. The force applied at the knife edge which would cause failure of the setscrew in compression plus sliding the knife back on the support was calculated as 12,330 lb.

The stone being approximately 5.5 in in diameter, and the feed advancing only 0.4785 in per cut, prevented the complete stone from entering the cutterhead. Each time a knife would strike that portion of the stone extending beyond the shear bar, it would tend to force it back through the feed rolls, thus causing the safety clutch to slip until the operator reversed the feed rolls and brought the stone out. Even though the knives apparently struck the stone with a glancing blow, the supports were subjected to a load of at least 12,330 lb, as shown in the following calculations.

Referring to Fig. 18 (and where R=resultant vertical force, P_1=force along the knife, P_2=force perpendicular to the knife, L=load exerted on knife due to tightness of nut, and U=coefficient of friction, assumed as 0.20), load P_1= force to cause failure of 7/16-in setscrew in compression plus UL=90,000 psi† × 0.0933 sq in† + 0.20L, but $L=T/0.20d$ where T is torque in inch-pounds and D is diameter of the bolt as reported by G. A. Maney in an article, entitled "Predicting Bolt Tension" published in *Fasteners*, vol. 3, no. 5.

Thus $L=1700$ in-lb/$(0.20\times0.75)=11{,}340$

$P_1=(90{,}000\times0.093)+(0.20\times11{,}340)=10{,}665$ lb

$P_2=10{,}665\times\tan 30=10{,}665\times0.577=6{,}154$ lb

$R=P_1/\cos 30=10{,}665/0.866=12{,}330$ lb.

It is quite evident that the cutterhead and knife support of this machine are ruggedly built and are able to withstand loads far in excess of normal wear and tear. It is practically impossible to make sure that a stone never enters the cutterhead. It is therefore desirable to have the damage occur at a point where it is most readily repaired.

The fact that the knife-adjusting setscrews failed in compression may have the advantage of a cushion effect and also allows the knife to slide upward and backward at an angle of 30 deg, thereby increasing the clearance between the knife and the shear bar, possibly allowing the obstruction to pass through.

†Hyland and Kommers: Machine Design.

Feed Interference. That feed interference does require added power in addition to resulting in poorer quality chopped hay is shown by a simple test involving fan blades. In this test the forage harvester was operated at identical speeds down identical windrows and the power determined for two runs. In the first test two fan blades were used behind each knife, the first at 45 deg and the second at 135 deg behind the cutting edge. Removing the second fan blade in test 2 resulted in a saving of 1.5 hp. The scoured area of the two fan blades is shown in Fig. 19.

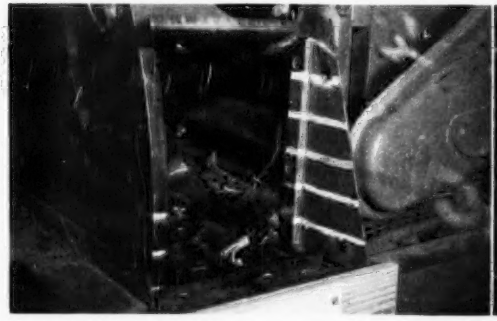
Cutterhead in Operation. Stroboscopic studies of the cutterhead in operation have verified what was already suspected by the paint study and target method of determining where material actually flowed. Photographs were made by a combination of stroboscopic and strobflash equipment of both a cutterhead using cast-steel (No. 2) or spoke-type knife supports with an external flywheel and the steel arm (No. 4) with support from the disk.

These studies were made at night in an open field with the forage harvester in a stationary position, being fed by laying a windrow of hay on a special conveyor. A special timer permitted varying the timing of the flash so pictures could be made at specific positions. These were selected at 5-deg intervals commencing 25 deg before the knife passed the shear bar or stationary knife and continuing 15 deg after. A study of these pictures (Figs. 20 and 21) reveals the following facts regarding material flow: (a) The knife does not pass through the material, but the material is accelerated to the speed of the knife and moves along with it, and (b) the cut material makes a 60-deg turn from the horizontal to a position with its major axis parallel to the surface of the knife.

Centrifugal Force. The fact that the material is moving along with the knife at 15 deg after the cutoff point, as shown by the strobflash pictures and the dense clogging that occurred when the end support was used (Fig. 6), indicates that centrifugal force is the dominant factor in moving material to the periphery of the housing where it is picked up by the fan wings and carried to the discharge point.

It can be shown by the basic formula for centrifugal force $CF=Wr\,\omega^2/g$ that the force acting to move the material radially in this cutterhead operating at 550 rpm varies from 50 to 180 times gravity in moving the particle from the inner edge of the throat to the housing band in the cutterhead under consideration. The magnitude of this force explains the dense conditions of material found trapped behind any obstruction to its radial movement.

From the nature of material movement within the cutterhead it seems that the amount of clear space between the supporting arm and the disk or housing should be related to the volume of material handled with each cut rather than the length of cut alone. A machine with a 14-in throat, 5½-in



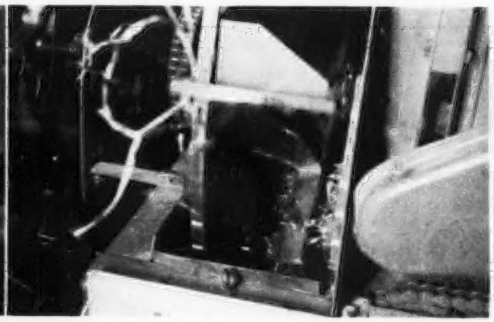


Fig. 20 *(Left)* Rear view: 15 deg after cutoff, showing cut material following knife. Stems aligned with face of arm • Fig. 21 *(Right)* End view: 20 deg after cutoff, showing cut material following knife. Note projection of feed for next cut and clearance provided

Fig. 22 Shows how material carried by the knife bolt is released at any time

feed roll lift and a 3-in cut, cuts off hay with a volume of 231 cu in per cut when operated at full capacity. This mass must find room behind the knife if it is to have unimpeded flow to the discharge point and minimize beating.

The cross-sectional area of the delivery elbow and spout must also be sufficiently large if throttling of material flow at this point is to be avoided. The width of the elbow and spout used in the experimental machine is equal to the housing width of 9 in. An efficient curve for a delivery spout is a cubic parabola of the formula $x=y^3$ with values of x from 0 to 1.4 or 1.5†.

Material Throwout Studied. One of the tests used in judging the efficiency of a knife support and fan blade position was to operate the cutterhead with the top portion of the housing open. If cut material is following the design path, then all of it should pass out through the discharge pipe. Any material thrown out of the housing at any other point indicates inefficient operation since this hay will contribute to the load of later fan blades and result in greater beating action.

Fig. 22 illustrates how material carried around by a projecting knife bolt is released at points other than the discharge point.

One of the refinements of the knife-mounting design which eliminated the throwout caused by material clinging to the bolt projections, was the addition of a cone-shaped deflector around the bolt head (Fig. 13).

Power and Capacity Trials. Several trials of horsepower and capacity were made with this cutterhead using different types of arm supports. Horsepower determinations were made by calibrating engine manifold pressure with operation on a prony brake. Calibration curves were prepared for five changes in engine-governed speed. In field operation, the manifold vacuum was recorded at four or five second intervals and an average reading for the run determined. Weight, moisture, and time data were recorded for each run. From this data the tons per hour and horsepower-hours per ton were calculated. To offset errors caused by engine deterioration, the engine was returned to the test stand periodically and another calibration curve prepared. The maximum capacity secured with two knives was 14.22 tons per hour of 26 per cent moisture hay requiring 21.6 hp average or 1.52 hp-hr per ton. Greatest efficiency was secured in a test run at 325 rpm when two tests were run averaging 1.04 hp-hr per ton. Comparative figures on other cutterhead designs are not available.

One of the advantages of the long cut and a two-knife machine is that sufficient hay-chopping capacity can be realized with lower cutterhead speeds. Reducing cutterhead speed is particularly desirable in improving the quality of the chopped hay. The lower limit of cutterhead speed with a two-knife machine will be determined by capacity, while with

‡Duffee, F. W.: New Developments in Forage Harvesting. AGRICULTURAL ENGINEERING 24:183-4, 186 (June, 1943).

TABLE 4. SUMMARY OF POWER AND CAPACITY TRIALS WITH HAY

1	2	3	4	5	6	7	8	9
Type arm	No. knives	Cutterhead rpm	Moisture when cut, %	Tons per hr	Tons per hr, 20% hay	Avg hp	Hp-hr per ton*	Hp-hr per ton†
4	2	325	8	4.88	5.60	5.1	1.04	0.91
4	4	350	56	16.35	‡	12.85	0.79	‡
3	2	450	30	10.25	8.56	16.1	1.56	1.80
2	2	500	19	8.77	8.9	13.6	1.55	1.53
2	2	550	26	14.22	13.1	21.6	1.52	1.64

*Column 6 divided by column 7 using observed tonnage.
†Column 5 divided by column 7 using moisture corrected tonnage.
‡No method of correcting for moisture.

a three or four-knife machine which has sufficient capacity at lower speed, the determining factor in speed will be delivery of material to the rear end of a trailing wagon. Delivery of material to the trailing wagon has been accomplished with cutterhead peripheral speeds as low as 3300 fpm, but a speed of 4400 fpm is more satisfactory to get full loading of the wagon. At these low speeds separation of leaf and stem and leaf pulverization (that is, dust) are practically zero, giving maximum quality of the product. The efficiency of the curvature of the delivery pipe is an important consideration, as a poorly designed curve may slow up the material excessively.

A further advantage of reduced speeds is the economy of power. Power to operate a forage harvester is divided between the following: (a) Friction and air movement of the empty cutterhead, which has been determined for the experimental cutterhead and is shown in Fig. 23, (b) power to operate the feeding mechanism, (c) power to shear the material, (d) power to accelerate the mass to peripheral speed, and (e) power to overcome friction between the cutoff material and the housing.

The exact division of power between these factors is unknown. Tests by F. W. Duffee with corn silage on stationary cutters has shown that blowing alone may require approximately 36 per cent or more of the total power.

The power required to accelerate the material can be calculated by determining the change in kinetic energy when the material is accelerated from 0 velocity to the peripheral velocity of the fan wings. Since the basic equation for kinetic energy is $MV^2/2$, this factor will vary as the square of the

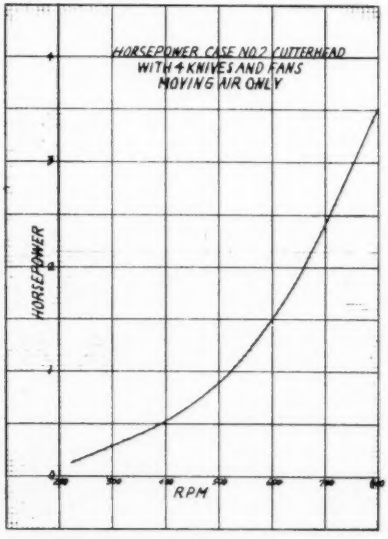


Fig. 23 Horsepower curve for empty cutterhead

cutterhead speed, if the quantity per hour remains constant in both cases.

The power to overcome friction against the housing is the product of centrifugal force, WV^2/gr, the coefficient of friction and peripheral velocity. Thus this factor varies as the cube of cutterhead speed.

A consideration of the basic formulas on the effect of speed on power requirements, the results of tests on power, and the very decided effect on hay quality leads to the conclusion that for hay the cutterhead should be operated at the lowest speed which gives desired capacity and satisfactory elevating characteristics.

Capacity Formula. The capacity of a forage harvester, if sufficient power is available, is determined by the volume and density of the forage as it passes under the feed roll.

These factors are expressed in the formula:

$$C = \frac{D \times H \times W \times L \times N \times R \times 60}{2000 \times 1728} = \frac{1.738 \times D \times H \times W \times L \times N \times R}{10^5}$$

Where C = Capacity in tons per hour

D = Density in pounds per cubic foot

H = Vertical throat opening with upper feed roll lifted to its maximum operating position

W = Width of throat at narrowest point in inches

L = Length of cut in inches

N = Number of knives

R = Revolutions per minute of cutterhead.

The capacity of the University of Wisconsin experimental machine, where $H=5.5$, $W=14$, $L=3$, $R=550$, and $N=2$, then becomes $C=4.42\,D$.

The density of the hay under the feed rolls, when the maimum capacity test was run, then becomes $D=14.22/4.42=3.22$ lb per cu ft.

That this density figure is not correct is known since the feed rolls during this test were not constantly at the top position. The density of long hay stored in a mow at 475 cu ft to the ton is 4.2 lb per cu ft.

The correct density figure is somewhere between these two but is higher than 3.22 since it is difficult to attain the theoretical capacity with actual field trials.

The maximum capacity with sufficient power available of a four-knife machine and a cutterhead speed of 400 rpm is $C=6.42\,D$.

Using the density figure obtained in field trials of 3.22 lb per cu ft this becomes $C=6.42\times 3.22=20.6$ tons.

Extremely Long Cut and Four-Knife Operation. It is desirable that the operations involved in changing the length of cut from hay to grass silage should be made as simple and as easy as possible within reasonable economy of construction.

Length of cut changes on most commercial machines involve three operations: (a) Changing the number of knives, (b) changing the speed of feed table by making one or more gear or sprocket changes and adjusting for chain length, and (c) changing the speed of the cutterhead by making pulley or sprocket changes and adjusting for change of belt or chain length.

It is particularly desirable to eliminate knife-changing operations which are both time consuming and hazardous. This can be done by operating as a four-knife machine for hay as well as silage, but presents problems in the way of knife clearance for a long cut, high feed-table speed, and extremely high capacity requiring considerable power. The knife clearance on this machine was ample to permit four-knife operation with a 3 in theoretical cut.

Lower feed-table speed and capacity were secured by operating the machine at the minimum speed, which would give satisfactory elevation. Thus, 400 rpm was selected as a cutterhead speed which met most of the requirements with a factor of safety for pulldown of engine speed when bunches were encountered since elevation could be secured at speeds as low as 300 rpm.

For the 1950 season a quick length of cut change was incorporated into this machine. This consisted of a double set of sprockets for changing cutterhead speeds by shifting a chain and a double-acting positive clutch permitting the selection of two different speeds of feed-table travel. The change from a 0.475-in cut for grass silage to a 3-in cut for dry hay can be made by one man in 3 to 5 min.

A special use for the clearance feature of this cutterhead was discovered in the 1950 season when the forage harvester stationary thresher method was given a trial at the college farm. For threshing purposes a length of cut greater than 3 in was desired. By removing two knives and arms, the machine delivered a 6-in theoretical cut. This was a considerable improvement over the 3-in length for threshing.

Straw from the windrow tends to enter the cutter nearly parallel to the feed-table travel and therefore the actual length of cut and the theoretical length of cut are more nearly alike.

Operation on Corn Silage. The forage harvester with the redesigned cutterhead has been used to harvest better than 800 tons of corn silage to date with excellent results. The cutterhead was designed primarily for a long cut in hay but the clearance features and streamlined flow have proved efficient in harvesting corn silage as well. Uniformity of cut was excellent. Power requirements are shown in Table 5.

TABLE 5. SUMMARY OF POWER AND CAPACITY TRIALS FOR CORN SILAGE

Arm No. 4		4 knives			Length of cut, 0.47 in	
1	2	3	4	5	6	7
Cutterhead rpm	Per cent moisture	Tons per hr observed	Calculated tons per hr at 70%	Avg hp	Hp-hr per ton*	Hp-hr per ton†
700	63	15.2	18.7	21.7	1.43	1.18
750	63	17.0	20.8	23.2	1.36	1.11
800	63	19.8	24.2	28.0	1.41	1.15

*Col 5 ÷ col 3 using observed tonnage.

†Col 5 ÷ col 4 using moisture corrected tonnage.

Horsepower-hours per ton requirements for this forage harvester are somewhat above the most efficient of the stationary cutters tested by F. W. Duffee in 1927. This may be partly due to the power required to operate the row-crop cutting and elevating mechanism which is included in the operation of the forage harvester but is not present in the stationary cutter.

SUMMARY

1 The primary objective of this investigation, to design a forage harvester cutterhead which will produce better-quality chopped dry hay, has been met to the extent that a substantial improvement in the product has been realized which dairy and animal husbandry departments of the Wisconsin College of Agriculture have graded as satisfactory.

2 Three changes were principally responsible: (a) The machine was designed to produce a longer cut which means fewer cuts per pound or ton of hay, (b) the above has permitted operation at low speed giving less impact to the hay, and (c) hay is not subjected to unnecessary beating or pounding as it passes through the cutterhead.

3 It has been established that most of the material flow after cutoff is in a radial direction and the knife does not pass through the material.

4 It is possible to chop hay at 3-in theoretical cut with approximately 1 hp-hr per ton at low speeds and approximately 1½ hp-hr per ton at speeds up to 550 rpm.

5 The information obtained from this study is dedicated to the improvement of the forage harvester and is free to the user without patent regulation.

The Resistance of Long and Chopped Hay to Air Flow

By Roy B. Davis, Jr. and Vernon H. Baker
ASSOCIATE MEMBER A.S.A.E. ASSOCIATE MEMBER A.S.A.E.

AMONG the first hay drying problems investigated was that of resistance of the hay to air flow and the effect of depth on this relationship. Much study has been devoted to this subject and some of the basic data have been previously presented (1, 2, 3)*. Investigators in hay drying research of the Virginia Agricultural Experiment Station and the Farm Electrification Division (BPISAE), U.S. Department of Agriculture, located in Blacksburg, Virginia, have had occasion to observe this relationship under a number of operating conditions.

In 1946, Hendrix(1) reported that the basic relationship between static pressure drop and variation of air flow through hay was an exponential expression of the form: $V = KP^n$ or $P = (V/K)^{1/n}$, where V is the velocity of the air in feet per minute or the volume Q in cubic feet per minute per square foot of mow area, P is the static pressure in inches of water column, and K and n are constants that depend on conditions of the test. In this expression K is the volume of air in cubic feet per minute per square foot of floor area blown through the hay when the static pressure developed is one inch water column, and n is the slope of the static pressure air flow curve when plotted on logarithmic graph paper. Hendrix indicated that some of the factors which might affect the numerical value of these constants were: type of hay, depth, density, and moisture content when stored. He further reported that the pressure drop through a well-planned hay-drying system could be closely approximated by assuming that n had a value of two-thirds. This assumption would mean that the numerical value of K would be most affected by the conditions of the test.

The inclusion of density as one of the factors affecting the static pressure air flow relationship introduces another very elusive factor. Zerfoss(2) points out that the important factors relating to hay density are maturity, moisture content, kind of hay, depth of storage and method of harvesting and handling before storage.

Equipment and Procedure. This summary presents observations made on tests where hay was handled as close as possible to the recommended conditions. The hay used was field-grown alfalfa, containing some grass. It was cut as near the recommended stage of maturity as possible and moved to the drier after remaining in the field approximately 24 hr. Part of the hay in these tests was dried long and part was chopped, then dried. The setting on the chopper was 2 to 2½ in. The actual length of cut would be from about 2 to 6 in with an average of approximately 3½ to 4 in.

In analyzing the data, it was found that there was no appreciable difference between the resistance of long or chopped hay to air flow. Due to this fact, no division between the data has been made. Variations in weather during the period in the field caused the moisture content, when stored, to vary from 40 per cent to 65 per cent(wet basis) for the different tests. Depths of hay from several drying tests varied from 2 to 12 ft. The relation between static pressure and air flow was observed at intervals during loading, drying, and unloading. At the time each observation was made, the weight of hay in the drier and its depth were recorded. Each of these observations was plotted on logarithmic graph paper and the value of K and n determined for the conditions under which the observations were made. The equipment in which these observations were made has been previously described(1, 3).

Variations Observed of K and n. Two methods of loading were used in these tests. In one group of tests, the hay was distributed by a man in the drying bin. He attempted to spread the hay uniformly, moving often and not confining his walking to any particular portion of the bin. It was thought that this might result in more even distribution of the hay over the drying bin. In the second group of tests, the hay was distributed in the bin from a platform on a level with the top of the bin. In these tests, no one was allowed to walk on the hay while it was being loaded.

This paper was prepared expressly for AGRICULTURAL ENGINEERING and has been approved by the director of the Virginia Agricultural Experiment Station as Paper No. S107-9 on the forage drying research project in cooperation with the U.S. Department of Agriculture.

The authors: ROY B. DAVIS and VERNON H. BAKER are, respectively, formerly associate agricultural engineer (BPISAE), U.S. Department of Agriculture, and associate agricultural engineer, Virginia Agricultural Experiment Station, Blacksburg, Va.

*Numbers in parentheses refer to the appended references.

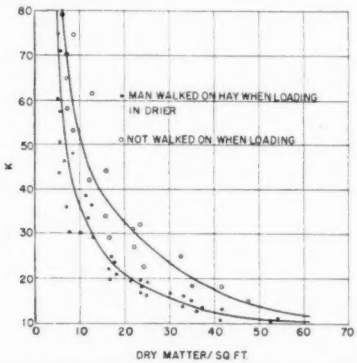


Fig. 1 Relation of K to depth and density of hay when loaded. Depth and density are expressed together in pounds as weight of dry matter per square feet of drier area. These data are the summation of a number of tests and show the effect that two methods of loading have on K

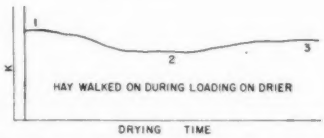


Fig. 2 A general curve showing how the constant K changes with drying time when hay was walked on during loading. The average decrease in K was 16 per cent for hay walked on and hay not walked on during loading. The points 1, 2, and 3 are to represent points before drying started, the zone of settling, and after drying, respectively. These points are referred to in Fig. 5(a) to (c). No drying time to be assigned to the time axis

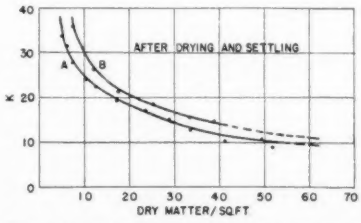


Fig. 3 Relation of K to depth and density of hay after drying and settling: curve A, man walked on hay when loading; curve B, not walked on

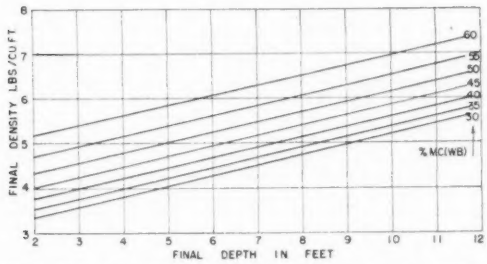


Fig. 4 Effect of final depth and initial moisture content on final density or density after drying in pounds of dry matter per cubic foot

Studying the data from the various tests revealed that the value of n remained fairly constant, but the value of K varied with time of drying, depth, and density of hay in the drier. After several methods of presentation were tried, the variation of K with the weight of dry matter per square foot of bin area appeared to give the best graphical picture. Even when using this relationship, the variations of K when the material was being loaded, during drying and when dry, were appreciable. The difference in loading methods showed an effect on the value of K. The graph of the variations in K while loading was in progress, when plotted against weight of dry material per square foot, is shown in Fig. 1. In this figure it will be noted that K decreases very rapidly as the weight of dry matter increases, but the rate becomes less as dry matter per square foot continues to increase. In general, the value of K is decreased when hay is walked on while it is being distributed.

When the value of n for each of the observations was plotted against weight of dry matter per square foot it was found to vary from 0.55 to 0.77. This variation of n probably can be attributed to the fact that different lots of hay with the same density in pounds per cubic foot will not have the same homogeneity. It was observed that the value of n was relatively constant as the weight of dry matter per square foot was increased. The arithmetic mean of n in these observations was 0.664. These data tend to confirm the results reported by Hendrix(1). The method of loading made no discernible difference in the value of n.

During drying, the value of n remained relatively unchanged, but the value of K decreased slightly, Fig. 2. This average decrease in the value of K from its value when loading was completed was 16 per cent.

The observations made after the hay was dry showed K would be slightly lower than when loading was completed, or before drying started. In most cases, the value of K decreased to a minimum during drying, but before drying was completed had increased slightly, though not to the level of its value when loading was completed. These data are likewise based on the observed variations in the value of K when plotted against the weight of dry matter per square foot, Fig. 3. Hay that was loaded into the bins without being walked on still showed slightly higher values of K for various values of dry matter per square foot, although this had not been as great as when loading was completed. The value of n showed the same pattern when plotted against the weight of dry matter per square foot, as was discussed earlier. The arithmetic mean of the values of n taken after the hay was dry was 0.668 — a slight but unimportant increase.

Settling During Drying. The amount of settling that might be expected varies with a number of factors. In studying the data from these tests, there appeared to be a significant trend between settling and moisture content when stored. Settling was expressed as a percentage of the original depth and moisture content was expressed as per cent (wet basis). The points do not give a very good fit in the linear approximation of the relationship between these two parameters, probably due to variables which could not be evaluated. The linear approximation, $Y = 19.68 + 0.17X$, (for 20 tests) represents what might be expected when hay is stored under average conditions of maturity and moisture. This equation was obtained by the least squares method. The minimum and maximum values of X for which the equation can be evaluated are, respectively, 30 and 65 per cent moisture content(wet basis).

Final Density When Dry. The effect of various factors on the final density attained by hay when it is dry is a rather lengthy subject. An attempt was made, however, to evaluate the trend indicated by observations of this series of tests on two of the principal factors enumerated by Zerfoss(2). These two factors are initial moisture content and storage depth.

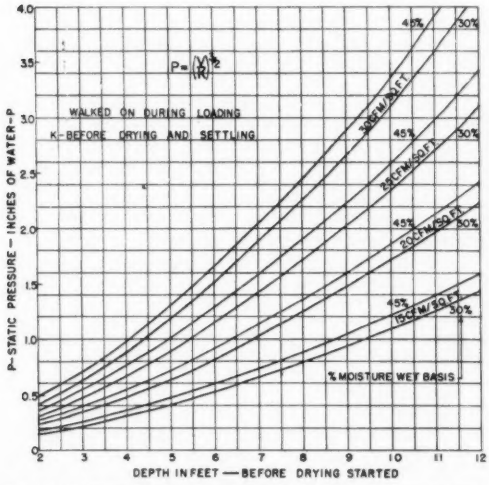


Fig. 5(a) Relationship of static pressure, depth of hay, air flow, and per cent moisture for long and chopped hay. Average length of cut, for chopped hay, 3½ to 4 in. Moisture samples taken during loading. Walked on during loading. (See point 1, Fig. 2 before drying)

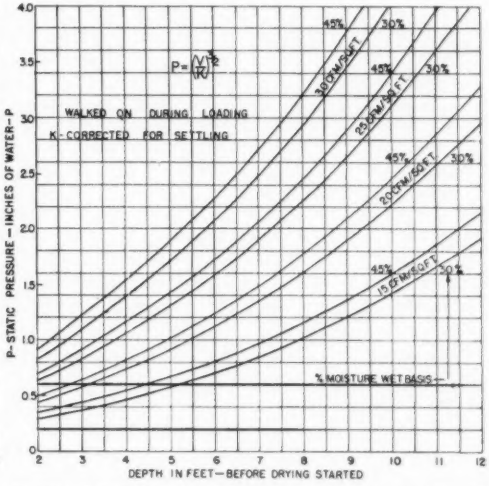


Fig. 5(b) Relationship of static pressure, depth of hay, air flow, and per cent moisture for long and chopped hay. Average length of cut, for chopped hay, 3½ to 4 in. Moisture samples taken during loading. Walked on during loading. (See point 2, Fig. 2, after settling)

When final depth, or depth when dry, was plotted against density when dry, expressed in pounds of dry matter per cubic foot, for each of the several tests, the relationship approached linearity on arithmetic graph paper. The slope of the curves for the various tests in this series were about the same. The trend indicated that as final depth was increased, the final density also increased. Methods of loading affected this trend slightly. When the material was distributed from a platform, not walked on, the final density at the lower depths was less, but the increase in density with increases in final depths was greater. When the effect of initial moisture content on final density at a given final depth was studied, considerable variations were observed in these data. The general trend, however, seemed to be that at a given final depth, density would vary with the initial moisture content of the hay. The combined effect of both final depth and initial moisture content on the final density is shown in Fig. 4. Since these data were insufficient to evaluate all of the factors involved, the results presented in Fig. 4 must be considered approximations and used as such.

Illustrative Problem. To illustrate the use of these data in the determination of the static pressure required for a given amount of air flow through long or chopped hay (2 to 2½ in setting on chopper) an illustrative problem is presented.

Assume that a hay drier is to be loaded to an initial depth of 8 ft with alfalfa hay having an initial moisture content of 45 per cent. This hay has been cut at the one-tenth bloom stage and contains a small percentage of grass. The formula for settling ($Y = 19.68 + 0.17X$, where Y represents settling and X the per cent moisture content), indicates that the depth of hay when dry would be 27.3 per cent less than its initial depth, or 5.8 ft. The data on initial moisture content, final depth, and final density shown in Fig. 4 indicate that a density of 4.9 lb of dry matter per cubic foot might be expected. The dry matter per square foot in this case is 5.8 ft x 4.9 lb of dry matter per cubic foot, or 28.42 lb of dry matter per square foot.

From Fig. 1 it is learned that when loading by the usual means of distribution (walked on when loading) of hay in the mow, the value of K would be 16.4. The value of n would be ⅔, and the lowest value that K would be expected to reach would be 13.8 [16—(16⅔ of 16.4) = 13.8, correcting K for settling]. After the hay was dry, Fig. 3, K would be 15.1. By substituting the three values of K, 16.4, 13.8, and 15.1 in the equation $P = (V/K)^{1/n}$, using a velocity of 15 fpm, we have 0.87, 1.14, 0.98 in of water static pressure for the conditions of before drying started, after settling, and after drying, respectively. These pressures do not include the resistance of the system itself. The highest value of P, 1.14, and the lowest value of K would be used for design purposes.

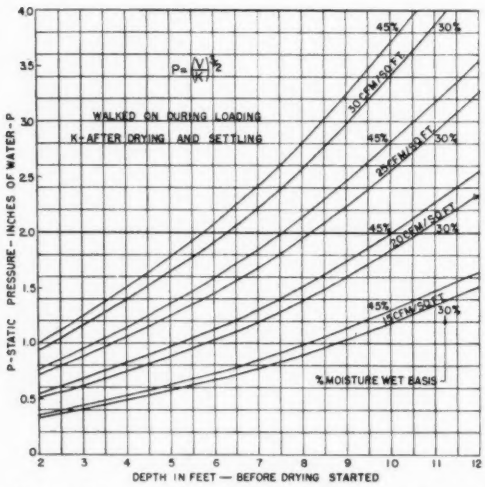


Fig. 5(c) Relationship of static pressure, depth of hay, air flow, and per cent moisture for long and chopped hay (2 to 2½ in theoretical setting on chopper). Average length of cut, 3½ to 4 in. Moisture samples taken during loading. Walked on during loading. (See point 3, Fig. 2, after drying and settling)

In order to facilitate the use of the data presented in this paper, curves showing the relationship between depth of hay in feet, static pressure, air flow, and moisture content are presented in Figs. 5(a), 5(b), and 5(c). The curves are drawn for hay with an initial moisture content of 30 and 45 per cent, wet basis. If the static pressure is desired for conditions for hay walked on that are not shown in Figs. 5(a) to 5(c), calculations may be made by using the procedure outlined in the illustrative problem. If the static pressures for hay not walked on are desired, these data may be calculated by following the example in the illustrative problem.

SUMMARY AND CONCLUSIONS

An attempt has been made to summarize the results of observations on the resistance of long and chopped hay to the flow of air as affected by several of the factors normally encountered in drying hay. The realization of the number of variables involved makes such a summary only an approximation or guide to the design of hay driers. The data presented in this summary give the effect of certain of the variables normally encountered. These observations indicate that:

1 There seems to be no appreciable difference between the resistance of long and chopped hay to air flow; that is, when the setting of the cut on the chopper was 2 to 2½ in, the length of the chopped hay varied from 2 to 6 in with an average of about 3½ to 4 in.

2 The value of the amount of air which one inch static pressure will force through a column of hay varies with its depth and density. When depth and density are combined into pounds of dry matter per square foot, the relationship between this factor and K becomes at least a second-degree curve, which shows asymptotic tendencies toward the X- and Y-axes.

3 The value of K in the equation $V = KP^n$ for a given condition usually decreases during drying to a minimum and then increases to a point slightly below its value when loading was completed and before drying started.

4 The method of loading has a considerable effect on K; that is, the amount of packing in distributing the hay over the mow.

5 The value of n remains relatively unchanged by these factors of distribution, density, and method of loading.

6 The amount of settling observed varies at least with the moisture content of the hay when stored, increasing as the moisture content is increased.

7 The effect of both final depth and initial moisture content on final density have been expressed as linear approximations, based on the observations of these tests.

The engineer should use his discretion as to which value of P to use in designing a hay-drying system. For the lower depths of hay, the minimum value of K obtained after settling would probably include a sufficient safety factor. At greater depths of hay, some compromise may have to be made between the minimum value of P and the maximum value of P that would be expected over a given drying period in order to arrive at a pressure that could be obtained with the electric power that is now available on farms.

The static pressures reported in this paper may be higher than those normally found in some field installations. This is due to the fact that in some field installations air is likely to be lost around the floor and edges of the drying system, whereas practically all of the metered air that was blown into the plenum chamber under the drying bins used in these tests was forced through the hay. *(Continued on page 100)*

Long-Time Performance of Some Clay Draintile

By D. G. Miller and P. W. Manson
FELLOW A.S.A.E. MEMBER A.S.A.E.

THE chief purpose of the work reported in this paper has been to secure information as to the frost-resisting properties of clay draintile installed at relatively shallow depths in farm drainage systems in the upper Mississippi Valley. By "clay draintile" is meant a burned product of clay or shale.*

Clay is defined in two ways: as an earthy aggregate consisting essentially of kaolinite or some nearly related hydrous aluminum silicate, and as any earthy mass that becomes plastic when wet. Usually a clay fulfills both these conditions.

Shale is a term frequently employed in the same sense as clay, but as a rule it is applied to hard laminated clays, generally of marine origin.

During 1948 and 1949 clay draintile were dug up from 19 Minnesota drainage systems. The length of time these systems had been in service ranged from 18 to 40 years and averaged slightly under 33 years. It is obvious that an ideal tile line for examination of this type would be one with variations in depth of cover from about 1 to 4 ft or more. Actually, none of the 19 tile lines examined met these ideal conditions and only three or four approximated them. It was not possible to determine the plant at which the tile of every system was made although this was done with reasonable certainty for all but 5 of the 19 systems. Tile from 10 of the 19 systems were presumably made of shale and 9 from surface clays.

This paper was prepared expressly for AGRICULTURAL ENGINEERING and is a report of work conducted under a cooperative agreement between the Bureau of Public Roads, U.S. Department of Commerce; the Division of Agricultural Engineering, University of Minnesota, and the Division of Water Resources, Minnesota State Department of Conservation. Since 1946 the graduate school of the University of Minnesota has allocated funds in order that completion of the manuscript might be expedited. In the files of the University, this is Paper No. 2587, Scientific Journal Series.

The authors: D. G. MILLER and P. W. MANSON, respectively, materials engineer, Bureau of Public Roads, U.S. Department of Commerce, and professor, division of agricultural engineering, University of Minnesota, University Farm, St. Paul.

*Grout, Frank K., Clays and Shales of Minnesota. U.S. Geological Survey, Bulletin 678 (1919).

SUMMARY AND CONCLUSIONS

Shale tile of "standard draintile" quality† were examined at 23 places in 10 drainage systems which had been installed 30 to 40 years. At 11 places, the tile had a covering greater

†Standard Specifications for Draintile. American Society for Testing Materials Designation: C4-24.

TABLE 1. FROST RESISTANCE OF DRAINTILE MADE OF SHALE AS DETERMINED BY TESTS OF TILE WHICH HAD BEEN IN SERVICE IN MINNESOTA FOR 30 TO 40 YEARS

(Note: The order of arrangement of the installations in the table is without significance)

Tile size in	No. tested	Time installed yr	Depth of top of tile, ft	Type of soil	Cover crop	General condition of tile	Crushing strength: lb per lin ft	Water absorption, per cent: Soaked 24 hr (a)	Water absorption, per cent: Boiled 5 hr (b)	Water absorption, per cent: Soaked 24 hr (c)	Water absorption, per cent: Boiled 5 hr (d)	Saturation coefficient*	No. freezings and thawing cycles to produce failure: Thawed in lab tank: Top half	Thawed in lab tank: Bot. half	Thawed by boiling: Top half	Thawed by boiling: Bot. half
Installation No. 3																
4	6	38	2.8	Clay loam	Cultivated	Good	1480	14.2	14.0	16.5	16.4	0.86	59	54	15	13
4	5	38	2.5	do	do	Good	1490	15.6	15.3	18.2	17.9	0.86	40	46	12	14
4	6	38	2.0	do	do	Good	1400	15.3	15.2	17.7	17.4	0.87	36	40	13	13
5	5	38	1.9	Peat	do	Good	1400	14.7	14.6	17.4	17.5	0.84	40	42	16	15
5	5	38	1.5	do	do	Good	1300	17.3	17.2	20.3	20.2	0.85	10	11	9	9
5	5	38	1.0	do	do	Good	1220	15.5	15.5	18.9	18.5	0.83	47	42	14	14
Average		38	1.9				1380	15.4	15.3	18.2	18.0	0.85	42	42	13	13
Installation No. 2																
4	5	35	3.0	Clay	Cultivated	Excellent	1320	11.3	11.7	12.8	13.7	0.87	66	67	20	19
5	7	35	2.8	do	do	Good	1290	15.6	15.6	17.9	18.0	0.87	25	28	8	8
6	7	35	2.5	do	do	Broken	(1300)	13.0	12.9	14.9	15.0	0.87	38	34	12	12
Average		35	2.8				1300	13.3	13.4	15.2	15.6	0.87	43	43	13	13
Installation No. P																
4	5	40	1.8	Clay	Cultivated	Spalled or cracked	(1200)**	18.5	17.6	19.7	19.1	0.93	11	13	7	7
Installation No. 5																
6	6	30	1.0	Clay loam	Pasture	Good	1160	10.4	10.5	12.7	12.7	0.82	70	71	28	27
Installation No. 6																
6	6	40	1.0	Silt	Pasture	Good	1140	18.4	18.7	20.2	18.5	0.91	12	12	9	7
Installation No. 4																
5	7	34	1.8	Clay	Pasture	Spalled or broken	(940)	21.0	23.6	23.5	23.4	0.99	14	13	8	8
Installation No. 9																
8	5	36	3.0	Clay loam	Cultivated	Good	910	16.2	16.2	21.6	21.8	0.83	59	58	14	11
8	6	36	2.5	do	do	3 good, 3 cracked	790	16.7	17.1	21.1	21.4	0.79	58	65	18	17
8	6	36	2.0	do	do	Cracked	780	19.4	19.5	21.9	22.1	0.88	46	54	14	15
8	6	36	1.5	Peat	do	Good	1330	12.9	12.6	16.6	16.4	0.77	77	89	20	22
8	4	36	1.1	do	do	Good	950	14.2	14.1	17.1	17.3	0.82	78	78	21	24
Average		36	2.0				950	16.5	16.7	19.7	19.8	0.82	64	69	17	18
Installation No. 12																
5	6	30	2.0	Peat	Cultivated	Good	1150	15.0	14.9	18.5	18.5	0.81	61	62	17	18
5	6	30	1.5	do	do	Good	1110	16.4	16.4	20.2	20.4	0.81	79	79	18	21
5	6	30	1.5	do	do	Good	1410	16.9	16.8	20.9	20.8	0.81	70	74	16	17
Average		30	1.3				1220	16.1	16.0	19.9	19.9	0.81	70	72	17	19
Installation No. 11																
4	6	39	1.5	Clay	Pasture	Good	1920	18.0	17.3	20.6	19.5	0.89	26	29	7	8
Installation No. J																
4	5	40	1.7	Clay loam	Grass	Spalled or broken	(1200)	8.8	8.6	10.0	10.2	0.86	63	77	26	30
Grand avg. of groups		36	1.7				1240	15.8	15.5	18.0	17.7	0.87	41	44	14	15

*Values in columns $\frac{(a)+(b)}{2}$ divided by values in column $\frac{(c)+(d)}{2}$.

**Crushing strengths in parentheses are estimated, mostly from old tests of other tile taken from plant stock piles.

than 1.8 ft and none of the tile showed any evidence of spalling due to frost action. At 12 of the 23 places examined, the tile had a covering which did not exceed 1.8 ft and at 3 of the 12 places there was definite frost action on the tile. Cracked or broken tile were found at three places without indication of frost action. At 2 of the 3 locations the depth of cover was 2.5 ft and at the other place it was 2 ft.

Surface-clay tile of "farm draintile" quality were examined at 20 places in 9 systems which had been installed 18 to 40 years. At 17 of the 20 locations the tile had disintegrated or were spalled or broken. There was spalling or disintegration due to frost action on the tile at 9 of the 20 places examined with depth of cover ranging from 0.8 to 2.5 ft. Tile were cracked or broken, without evidence of frost action, at 8 of the 20 places examined. The depth of cover at these 8 places ranged from 1.7 to 3.0 ft. Only at 3 of the 20 places examined were the surface clay tile in good condition. The depths of cover at these three places were 1.5, 3.0, and 3.5 ft.

Not all, but most, of the shale tile upon which this report is based were of standard draintile quality in crushing strength and frost resistance and the performance records were generally good.

None of the surface-clay tile upon which this report is based met standard draintile requirements and the performance records ranged from fair to poor.

Details of Field Examinations. There have been condensed in Tables 1 and 2 certain essential facts pertaining to the field exposure conditions at the various tile installations examined, together with the averages of the physical tests which were made on the tile after they were brought to the laboratory.

The data of Table 1 reveals that the shale tile were in good condition at 17 of the 23 places examined and were spalled or cracked at the other 6 places. Tile in good condition were found with depths of cover from 0.5 to 3 ft and cracked or spalled tile were found with depths of cover from 1.7 to 2.5 ft.

Study of the data of Table 2 in which are recorded tests of drain tile made of surface clays, shows that at 17 of the 20 places examined the tile were spalled or broken. At 9 places tile were spalled or disintegrated and none of these had a depth of cover exceeding 2.5 ft. There were 8 places at which tile were broken with appreciable spalling and these had depths of cover between 1.7 and 3.0 ft. In general, the examinations of the tile made of surface clays suggest that there was a tendency for those with the depths of cover from 2 to 2½ ft to fail by cracking and those with the lesser depths of cover to fail by spalling.

There have been summarized in the following table the essentials of the physical tests of the 244 tiles of Tables 1 and 2 on the basis of the grand averages of groups:

Raw material	Time installed, yr	Avg. depth of cover, ft	In good condition, %	Crushing strength, lb per lin ft	Water soaked, 24 hr at room temp, %	Absorption, boiled 5 hr, %	Saturation coefficient	No. of freezing and thawing cycles to produce failure: Thawed in lab tank	Thawed by boiling
Shale	36	1.7	74.8	1240	15.6	17.8	0.87	42	14
Surface clay	28	1.8	17.7	970	26.6	28.9	0.92	14	9

TABLE 2. FROST RESISTANCE OF DRAINTILE MADE OF SURFACE CLAYS AS DETERMINED BY TESTS OF TILE WHICH HAD BEEN IN SERVICE IN MINNESOTA FOR 18 TO 40 YEARS

(Note: The order of arrangement of the installations as recorded is without significance)

Tile size, in	No. tested	Time installed, yr	Depth to top of tile, ft	Type of soil	Cover crop	General condition of tile	Crushing strength, lb per lin ft	Water absorption, per cent: Soaked 24 hr: Top half (a)	Soaked 24 hr: Bot. half (b)	Boiled 5 hr: Top half (c)	Boiled 5 hr: Bot. half (d)	Saturation coefficient*	No. freezings and thawing cycles to produce failure: Thawed in lab tank: Top half	Thawed in lab tank: Bot. half	Thawed by boiling: Top half	Thawed by boiling: Bot. half
							Installation No. (G)									
10	5	25	1.5	Clay loam	Cultivated	Disintegrated	(810)**	(21.6)***	21.6	(23.8)***	23.8	0.91	0	28	0	14
							Installation No. (F)									
5	7	20	1.7	Clay loam	Grass	Broken	(1050)	26.7	28.4	28.5	28.3	0.97	10	11	10	12
							Installation No. (C)									
7	5	18	0.8	Clay loam	Meadow	2 good, others broken or spalled	(1150)	18.8	18.9	22.8	22.3	0.84	46	41	22	24
							Installation No. (E)									
8	6	20	1.7	Clay loam	Pasture	Broken	(750)	32.9	32.9	34.5	34.7	0.95	16	14	9	9
8	5	20	0.9	do	do	Disintegrated	(750)	(31.1)***	31.1	(34.2)***	34.2	0.97	0	9	0	6
Average		20	1.3				(750)	33.0	33.0	34.3	34.4	0.96	8	11	4	7
							Installation No. (7)									
10	6	34	2.3	Clay	Pasture	Broken lengthwise	(1100)	28.7	28.8	31.0	31.2	0.92	11	10	7	9
							Installation No. (8)									
6	6	31	1.5	Muck	Pasture	Good	910	34.0	34.3	36.7	36.8	0.93	11	10	8	8
							Installation No. (B)									
5	5	40	3.5	Clay loam	Cultivated	Good	1110	23.7	23.7	26.7	26.7	0.89	16	16	11	10
5	5	40	3.0	do	do	Good	990	24.8	25.0	27.8	28.1	0.89	13	15	9	13
6	5	40	2.1	do	do	Disintegrated	(1000)	26.3	25.8	29.1	28.8	0.90	11	12	8	10
6	5	40	2.0	do	do	Broken	(1000)	25.9	30.1	28.0	27.1	1.02	11	10	13	14
6	9	40	1.2	do	do	Disintegrated	(1000)	27.1	25.8	30.3	27.7	0.91	10	11	11	9
Average		40	2.4				1000	25.6	26.1	28.4	27.7	0.92	12	13	10	11
							Installation No. (1)									
7	5	36	3.0	Clay loam	Cultivated	Broken	(1000)	25.4	25.6	27.9	27.9	0.91	9	10	7	7
7	7	36	2.5	do	do	Broken	(1000)	26.6	26.6	29.1	28.6	0.92	9	11	8	8
7	5	36	2.0	do	do	Top spalled off	(1000)	(26.7)***	26.7	(29.1)***	29.1	0.92	0	10	0	7
6	6	34	3.0	do	do	2 good, 4 broken	1030 (2)	24.3	23.8	26.6	26.6	0.90	11	15	7	7
6	6	34	2.5	do	do	Spalled or broken	800	25.2	25.2	27.5	27.6	0.91	13	15	9	10
5	5	34	2.0	do	do	Some spalling	(1000)	24.3	23.0	26.9	25.6	0.90	21	29	13	15
5	5	34	1.5	do	do	Top spalled	(1000)	24.1	24.1	27.7	27.1	0.90	13	19	9	10
Average		35	2.4				(980)	25.4	25.1	27.8	27.5	0.91	11	15	8	9
							Installation No. (10)									
8	5	34	2.5	Clay loam	Cultivated	Broken	950	24.4	24.4	27.7	27.4	0.89	12	10	8	8
Grand avg. of groups	28	1.8					970	26.5	26.7	29.0	28.8	0.92	13	16	9	11

*Values in columns $\frac{(a)+(b)}{2}$ divided by values in columns $\frac{(c)+(d)}{2}$.

**Crushing strengths in parentheses are estimated, mostly from old tests of other tile taken from plant stock piles.

***The top half was disintegrated and the absorption value in parentheses was assumed to have been the same as the bottom half.

TABLE 3. CORRELATION OF ABSORPTION AND FROST RESISTANCE OF CLAY DRAINTILE FROM 27 MINNESOTA AND IOWA TILE PLANTS

(Tests tests were made during 1928-1930 on tile collected from plant stock piles)

Reference nos.	Raw material	Tile size, in	Tests of ordinary plant output*		Maximum absorptions (per cent) of individual tile in each group which met freezing and thawing requirements of ASTM Designation C4-24	
			Crushing strength, lb per lin ft	Absorption (Boiled 5 hr), per cent	Standard draintile (36 cycles)	Extra-quality draintile (48 cycles)
1(E), 1(7)	Surface clay	6	760	34.3	None passed	None passed
2(F), 2(8)	Surface clay	6	1040	31.6	15.1	14.9
3(10)	Surface clay	4	1020	27.6	None passed	None passed
4(2)	Surface clay	6	1130	23.5	20.0	19.0
5	Surface clay	8	No test	23.6	None passed	None passed
6(9)	Surface clay	8	870	22.1	14.0	13.0
7	Shale	5	1760	21.9	20.8	20.5
8	Surface clay	4-5-6	No test	20.5	20.2	18.9
9	Surface clay	6	No test	20.1	19.7	None passed
10(3)	Shale	5	1980	15.8	15.7	15.6
11	Shale	5	780	15.2	15.0	14.6
12	Surface clay	10	No test	14.7	13.0	13.0
13	Shale	5	2190	13.2	15.0	14.5
14	Shale	6	1840	13.0	20.0	18.9
15	Shale	8	1500	11.3	16.3+	16.3
16	Shale	6	1650	10.7	11.9	11.8
17	Shale	5&6	1790	9.5	13.3+	11.6
18	Shale	6&7	1950	9.3	14.2+	14.2+
19	Shale	6	2160	9.2	13.5	13.0
20	Shale	4	2390	9.0	13.3+	13.3+
21	Shale	4	1430	9.0	13.7	13.2
22	Shale	5	2120	8.6	11.4+	11.4+
23	Shale	6	1700	7.7	10.9	10.5
24	Shale	5	1520	7.5	11.2	11.0
25	Shale	8	2070	5.1	13.1+	13.0
26	Shale	6	2590	5.0	7.7+	7.7+
27	Shale	6	2680	3.6	8.2+	8.2+

Note: Figures and letters in parentheses in the first column refer to installations as designated in Tables 1 and 2.
*Each test result is the average of 15 or more tile.

The saturation coefficient in the foregoing table and in Table 1 and Table 2, is calculated essentially as prescribed by the Standard Methods of Sampling and Testing Brick, ASTM Designation C67-44, except that the percentages of water absorption are used as shown below:

$$\text{Saturation coefficient} = \frac{p_2}{p_3}$$

where p_2 = per cent of water absorption, soaked at room temperature for 24 hr

p_3 = per cent of water absorption, boiled 5 hr.

It is evident from the data that the shale tile with their lower absorptions had much better durability records than did the surface clay tile. Nearly 75 per cent of the shale tile were in good condition after 36 years, whereas less than 18 per cent of the surface clay tile were in good condition after 28 years. The depth of cover averaged approximately the same for the two types of tile, 1.7 ft for the shale tile and 1.8 ft for the surface clay tile.

The shale tile of these tests met the crushing strength requirements of 1200 lb per linear foot for standard draintile. The shale tile, with 42 cycles for failure when thawed in water at room temperatures, went well over the freezing requirements of 36 cycles for standard draintile.

The surface-clay tile of these tests met the strength requirements of 800 lb per linear foot for farm draintile but did not meet the freezing requirements of 24 cycles, averaging but 14. With the exception of the tile at installation C of Table 2 the results of the freezing and thawing tests of the surface-clay tile were reasonably consistent with their long-time performance. The tile at installation C stood better than 40 cycles before failure in the laboratory. In the field the tile were covered to a depth of only 0.8 ft and their failure in service from cracking and spalling was not surprising.

It is significant that the surface clay tile at installations F, 7, 10, and 8 of Table 2 did not show appreciable frost action after periods of exposure of 20, 34, 34, and 31 yr, respectively, even though none of these tile were of high frost resistance and none had a soil covering that exceeded 2.5 ft. Therefore, it must be concluded that frost action on draintile in service is less severe than has been generally assumed. To cite a specific example, note that the tile at installation 7 failed to meet farm draintile requirements of 24 freezing and thawing cycles, yet in service with a cover of 2.3 ft the tile showed no appreciable frost action after exposure for 34 yr (Tables 2 and 3).

No disintegrated, or even badly spalled, shale or surface-clay tile were found at any of the 8 places in the 19 drainage systems examined during 1948 and 1949 where the depth of cover exceeded 2.5 ft. In view of this, it appears that there were not many freezing and thawing cycles in these particular tile systems below a 2.5 ft depth.

Depth and Frequency of Frost Penetration. Exact data are meager as to depth and frequency of frost penetration in farm fields where most draintile are installed. Such data as are available are extremes compiled for use in the design of foundations for buildings and other types of superstructures. Extremes, while of some use in connection with probable frost action on draintile, do not by any means tell the whole story because of the following and perhaps other factors:

1 Frequency and duration of extremes of winter temperatures
2 Depth and duration of snow cover
3 Depth and type of soil cover
4 Moisture content of the soil at the tile level
5 Physical condition of the soil cover — fall plowed, etc.
6 Vegetative cover
7 Quantity and source of water carried by the tile.

It is evident that much more research is necessary than is covered by this report before it will be possible to establish a satisfactory relationship between the frost resistance of clay draintile as determined by standard laboratory tests and durability under field conditions.

APPENDIX

In 1930, a report was prepared on the frost-resistant properties of clay draintile made at 27 Minnesota and Iowa plants which had furnished most of the tile used in Minnesota up to that time. Eighteen of the 27 plants made tile of shale while 9 used surface clay. This unpublished paper, based entirely on laboratory tests of tile collected from individual plant stock piles, contains considerable information that is closely related to the long-time durability studies of the clay tile which were examined in 1948 and 1949.

Absorption-test results of tile from one plant compared with absorption-test results from other plants have little significance. However, comparison of results of tests of individual tile from any given plant are reasonably reliable as indicative of relative frost resistance of tile from that particular plant. Inspection of the data of Table 3 shows that in the case of 15 of the 27 plants listed, the average absorption of the ordinary output of tile from a given plant was less than the maximum absorption of individual tile from that same plant which met the freezing and thawing requirements for extra-quality draintile as defined in the Standard Specifications for Drain Tile, A.S.T.M. Designation C4-24. These are plants 13 to 27, inclusive, all of which employed shale as the raw material. The data further show that, in the case of 12 out of these 15 plants, the average absorption of the ordinary plant output exceeded the 7 per cent *(Continued on page 100)*

Determining the Relative Wear Resistance of Metals

By I. F. Reed and E. D. Gordon
MEMBER A.S.A.E. MEMBER A.S.A.E.

THE development and adaptation of improved materials for making cutting edges and soil-working faces of tillage tools have been among man's foremost problems since the introduction of agriculture as a science. No doubt the early agriculturists using crooked sticks sought out what they thought to be the best curves and selected and seasoned woods to produce surfaces they thought to be near optimum. Records through the eleventh to eighteenth centuries indicate that there was considerable interest in improving tillage implements. Soil-working faces were plated with iron. This was a help but the iron wore away rapidly and failed to scour under many soil conditions.

Development in materials for soil-working faces and edges of tillage tools has made marked strides since 1800, but the development in this field still lags behind the advancement made in other fields. The first outstanding improvement was the development of a process for chilling the undersurface of cast-iron shares. This increased their life and, since the top surface wore away faster than the bottom surface, the edge tended to remain sharp. The introduction of the steel plow in 1837 and the use of chilled plow shares brought great improvements in tillage equipment during the first half of the nineteenth century. For the most part, developments since that time have been improvements of these materials by use of various analyses, alloys, and manufacturing techniques (2, 13, 14, 15).* The agricultural engineers' conception of developments of materials for tillage tools was stated by Zink et al (19) as follows: "Many improvements have been made in metals used in various industries. In fact, these changes are the very substance of the existence of a number of our later industries. No one will deny that tillage implement materials have not kept pace with other developments in the field of metallurgy." These authors pointed out that much of the skill of the country blacksmiths had been lost even in 1936. In most areas it is now difficult to find a blacksmith who will attempt to reshape or temper tillage tools. This changes the specification placed on materials for tillage tools in that long-wearing, shock-resisting materials that shed sticky soils may be used without thought in most cases as to whether or not they can be reshaped and heat-treated by local blacksmiths or mechanics. Discarding worn or dulled soil-working edges and faces, as is done with safety razor blades, is becoming popular.

Tests at the U.S. Tillage Machinery Laboratory and by workers at other experimental stations and laboratories show that hardness measurements alone cannot be taken as an index of the wear resistance of a material when used in or for handling soils (1, 17, 18). Wear resistance will correlate with hardness when comparing the effects of various heat-treatments for one analysis, but the wear resistance of two samples having the same hardness but of different alloys may be markedly different.

Since hardness measurements alone failed to give a true measure of the relative wear resistance of materials for tillage tools and field testing is a drawnout and costly process, laboratory methods which have been used for measuring wear resistance were investigated. Haworth (8) classifies these units under the five categories: (a) fixed abrasive, (b) sandblast, (c) ball mill, (d) abrasive lap, and (e) rotating wheel.

1 Fixed abrasive units may be represented by grinding wheels. The principal disadvantage of this type of unit is that grinding takes place at a relatively uniform rate in spite of the type of material being tested.

2 Sandblast tests, according to Rosenberg (15), do not differentiate between many materials which are known to have widely varying wear-resisting characteristics.

3 Ball-mill tests apparently are not applicable to tests of materials for tillage tools. They require specimens of definite shapes that cannot be produced readily from some of the better materials used for tillage tools.

4 Abrasive-lap tests may be represented by the wear-test machine developed and used by Zink et al (19). It is effective for tests of materials for tillage tools. Three disadvantages of this type of test are as follows: (a) Samples must be prepared carefully as to shape, (b) Test runs require approximately 100 hr, (c) Variation in the moisture content of the abrading medium during or between tests affects the rate of wear. Haworth (8) reports that the use of silicon carbide as the abrading agent accelerates the wear "but the results cannot always be used with complete assurance for applications involving less abrasive materials."

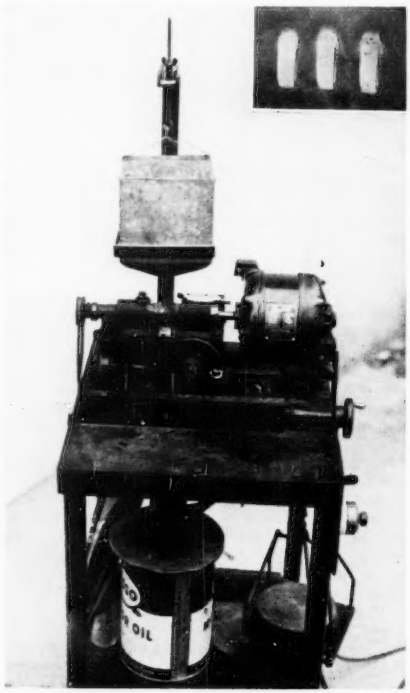


Fig. 1 The USDA wear-test machine with specimen in position for test. (Inset) A sample showing typical wear-test grooves and marks made by Rockwell Brale

5 The rotating-wheel-type wear testing machine may use either a dry or wet abrading medium. The sand or other abrading material is fed or carried between the face of the abrading disk and the test sample. The original unit for this type of test was developed by Brinell. Its make-up, operation, and effectiveness are discussed fully by Haworth(8) and Rosenburg (18). Due to the simplicity of this test machine, its effectiveness, the rapidity with which tests could be made, and the fact that results for duplicate tests checked closely, the principles developed by Brinell were used in the wear-test machine built at the U.S. Tillage Machinery Laboratory and used in this study.

The USDA Wear-Test Machine. The USDA wear-test machine is shown in Fig. 1. The principles involved in the machine are shown diagrammatically in Fig. 2. The test sample *A* is held in a frame so designed that it can be

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The author: I. F. REED, senior agricultural engineer, U.S. Tillage Machinery Laboratory, Auburn, Ala., and E. D. GORDON, agricultural engineer, Maremont Automotive Products Inc., Chicago, Ill.

*Numbers in parentheses refer to the appended references.

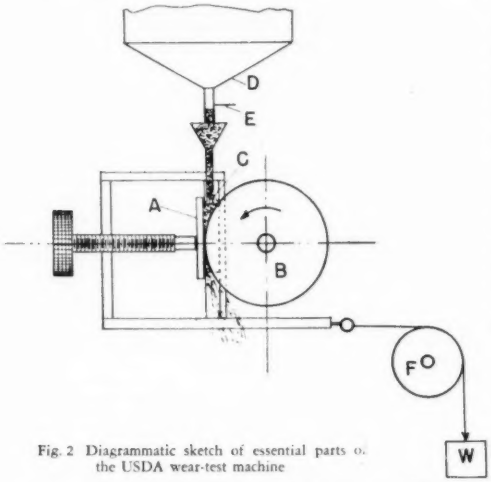

Fig. 2 Diagrammatic sketch of essential parts of the USDA wear-test machine

moved to or from the abrading disk *B*. During a test the sample is held against the abrading disk with a uniform pressure by weight *W*. Carefully screened sand flows from hopper *D* past valve *E* to point *C* where it is carried between the abrading disk and the test sample. Abrading disk *B* is approximately 4 in in diameter, 3/16 in thick, and is cut from Armco or other relatively uniform soft iron plate. It is driven at approximately 45 rpm. A test consists of operating the abrading disk a certain number of revolutions to give a selected lineal travel of a point on its circumference. The sample (Fig. 1, insert) is weighed before and after the run. The relative wear resistance of the samples is shown by their loss in weight measured to the nearest ten thousandths of a gram. A suction fan is arranged to remove dust created by the abrading operation.

Sand. Dry Norfolk sand was screened and only the fraction that passed through a 40-mesh screen and over an 80-mesh screen was used. This gave grains varying from approximately 0.077 to 0.0165 in in diameter. Since this material proved to be so effective, no other type of sand or range of particle sizes were tried in this study. The sand is used dry.

Effect of Length of Run. It was found that the loss of weight was proportional to the length of the test as shown in Fig. 3. In view of this fact, 300 lineal feet of travel of a point on the abrading disk was selected as the length of test. This required 289 revolutions of the disk when new and measuring 4 in in diameter. The diameter of the abrading disk was measured after each test and the number of revolutions per test increased one revolution for each loss of 0.014 in in diameter. Abrading disks were discarded when worn to a diameter of 3.89 in. The number of revolutions of the abrading disk was recorded by a counter on the unit. The length of the test was manually controlled.

Effect of Pressure. The data in Fig. 3 show that the loss of weight on a test sample varied proportionally with the weight holding the sample against the abrading wheel to a weight where the pressure apparently crushed the sand particles too finely. Since the sand broke down at the higher pressures, a load of 12 lb was selected for use in all comparative tests. The combination of 289 revolutions of the abrading disk, with the sample held against it under a 12-lb load, produced weight losses of approximately 0.1 g for annealed SAE 1095 steel and for many of the steels used in tillage tools. Losses as low as 0.06 g were measured for samples of extremely hard materials. Data for duplicate tests checked within 4 per cent.

Effect of Width of Disk. One series of tests was made using a disk ¾ in wide in place of the 3/16-in width used in all other tests included in this discussion. This arrangement was used to spread the wear over a larger area and thus reduce the depth of groove when testing plated, soft-center, or hard-surfaced materials. This study indicates that this type wear-test machine is not effective for measuring the relative wear of surface materials that are less than 0.025 in thick.

Test of Disk Blade Materials.[1] Data comparing the relative wear for both field tests and laboratory tests on 16-in disks made from five types of steel and 18-in disks from four types of steel are shown in Fig. 4. Field tests were made by carefully weighing and measuring 4 or 5 disks of each type of steel and size, then placing them on farmer-owned tandem disk harrows to be used during the regular seedbed preparation season. The locations of the disks on each harrow were changed periodically through the time they were used so that no disk remained in a favorable position throughout the test. All disks were carefully measured and weighed at the end of the test. The average weight losses for each type of steel and size are shown by the open bars in Fig. 4. Samples for test by use of the USDA wear-test machine were cut from 2 to 3 disks of each type of steel for each side. The average weight

[1]Disk blades furnished by and field tests supervised by Maremont Automotive Products, Inc.

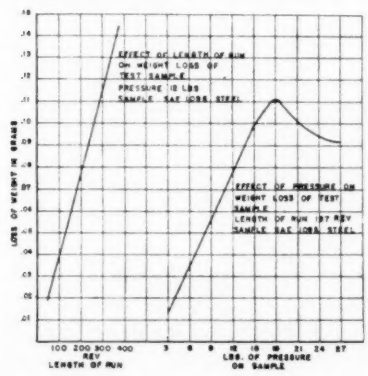
EFFECT OF LENGTH OF RUN ON WEIGHT LOSS OF TEST SAMPLE
PRESSURE 18 LBS
SAMPLE SAE 1095 STEEL
EFFECT OF PRESSURE ON WEIGHT LOSS OF TEST SAMPLE
LENGTH OF RUN 197 REV
SAMPLE SAE 1095 STEEL
LOSS OF WEIGHT IN GRAMS
100 200 300 400
REV
LENGTH OF RUN
3 6 9 12 15 18 21 24 27
LBS. OF PRESSURE ON SAMPLE

Fig. 3 These curves show the effects of length of run and test pressure on weight loss of steel samples

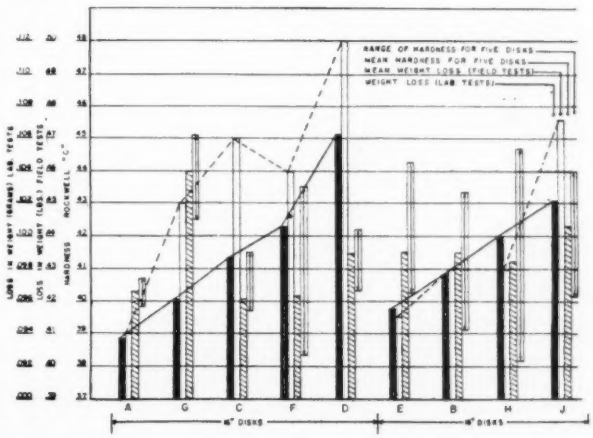
RANGE OF HARDNESS FOR FIVE DISKS
MEAN HARDNESS FOR FIVE DISKS
MEAN WEIGHT LOSS (FIELD TESTS)
WEIGHT LOSS (LAB TESTS)
LOSS IN WEIGHT (GRAMS) LAB TESTS
LOSS IN WEIGHT (GRAMS) FIELD TESTS
HARDNESS
ROCKWELL "C"
A G C F D E B H J
16" DISKS
18" DISKS

Fig. 4 These curves compare the relative laboratory and field weight losses for several types of steel and for 16- and 18-in range are also shown

losses for three runs on each sample are shown by the solid bars in Fig. 4. The cross-hatched bars show the mean Rockwell C hardness for 5 disks of each steel and size. The range of hardness for each group of 5 disks is also shown. Note that the hardness varied as much as 6.4 points, or approximately 15 per cent. Data for laboratory wear tests on samples from different disks of the same type of material varied a maximum of 5 per cent. Disks used in this study, except for samples C, D, and E, were regular production disks made by four manufacturers and obtained from dealers in the South. Samples C, D, and E were made up from new materials the manufacturer hoped might produce superior tools. The data in Fig. 4 show that they were not superior to the manufacturer's regular production disks, samples A and B.

Comparison of Laboratory and Field Data. The samples for both sizes of disks are arranged in order of their weight loss in the laboratory tests. The lines connecting the tops of the bars for the laboratory and field tests show that data for the two types of tests correlate very closely. First glance gives the impression that the field data would place samples C and F in reverse order. It is to be noted, however, that the differences in the measured weight losses in the field for these disks were only 0.01 lb and the difference in the weight loss for the laboratory tests was only 0.002 g. These differences amount to approximately 2 per cent of the values, so are within the probable experimental error, especially for the field tests. For all practical purposes these two samples should be classed as equal by both methods.

Data for hardness of the disk blades does not correlate with wear. For practical purposes the disks, except for sample G, would be classed as belonging to the same hardness group, as manufacturers allow a tolerance of 4 points, which would cover the range from 38.5 to 42.5. Though the allowable tolerance is supposed to be only 4 points, the hardness for disks in at least three groups varied more than this amount.

SUMMARY

Various methods of measuring the wear resistance or relative wear of metals that may be used for soil-working tools are discussed. A simple wear-test machine developed at the U.S. Tillage Machinery Laboratory and its operation are explained. Data showing the correlation between the laboratory wear tests, field wear tests, and hardness of the samples are shown.

Preliminary tests made using the USDA wear-test machine compare on a practical basis with field tests. Replica wear tests can be made on a metal sample in approximately 30 min, whereas field tests require hours of field operation that may necessarily be spread over a period of several months. The laboratory tests are made on samples approximately 2 in square. Field scale tools (disk blades, plowshares, etc.) must be made from each new material for field tests. Since laboratory and field tests compare practically, small samples of all materials that might be used for tillage tools can be tested by use of the USDA wear-test machine. Those that show superior wear qualities can be made into test tools to determine whether or not they have the other characteristics such as shock resistance, tendency to scour, etc., necessary for superior tillage tools. This procedure should markedly reduce the cost of selecting superior materials for tillage tools.

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The Resistance of Hay to Air Flow

(Continued from page 94)

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Long-Time Performance of Draintile

(Continued from page 97)

maximum allowable limit for shale tile of extra quality in the above-mentioned Standard Specifications. For example, in the case of plant No. 14, having an average ordinary plant output absorption of 13.0 per cent, individual tile with absorption as high as 18.9 per cent passed 48 cycles of freezing and thawing. This indicates that there was an excellent working margin for frost resistance of tile from this plant. By varying degrees, the same situation for tile from all the plants numbered from 13 through 27.

The 1930 tests summarized in Table 3 show that the tile which passed the freezing and thawing requirements of 48 cycles for extra-quality draintile were of a quality that was all the name implies. Eighty-three per cent of 840 tile from the 27 plants also passed 96 cycles, or twice the requirements. In other words, extra-quality draintile of clay are well suited for extreme conditions of frost action.

It is evident from the data of Table 3 that the water absorption of tile of the ordinary plant output from plants numbered 1 through 12 was much higher than the maximum absorption allowable for standard draintile. The tests show that these tile with high absorption values have low frost resistance and do not quite meet the requirements set forth for standard draintile in the freezing and thawing test carried out in the laboratory.

The surface-clay tile with high absorptions and low frost resistance from plants 1 through 6 in Table 3 are of particular interest in connection with these long-time durability studies because tile from plants Nos. 1, 2, 3, 4, and 6 which were examined after having been installed *(Continued on page 101)*

A Plotting Machine for the Multiple-Point Potentiometer Chart

By U. F. Earp and V. H. Baker
JUNIOR MEMBER A.S.A.E. MEMBER A.S.A.E.

THE multiple-point temperature-recording potentiometer has become a popular time-saving instrument for recording temperatures in agricultural research. The recording instruments that are now available will record temperatures automatically at regular intervals on a continuous chart from 16 points or less. Tests conducted by agricultural engineers of the Virginia Agricultural Experiment Station, show that about 1 to 1½ man-hours are required to transfer and plot the records from a single thermocouple for a 24-hr test from the potentiometer chart to coordinate paper. This represents considerable effort when tests of 24 hr or more involving 16 different points are to be plotted.

A plotting machine that will transfer the data from a potentiometer chart to coordinate paper in the form of a curve has been developed. The fourth model of the machine, Fig. 1, will plot curves at the rate of 3 ft or more of recorder chart per minute. It would take about 8 min to plot the records from one thermocouple for a 70-hr test if the chart on the recording potentiometer is operated at a rate of 4 in per hr.

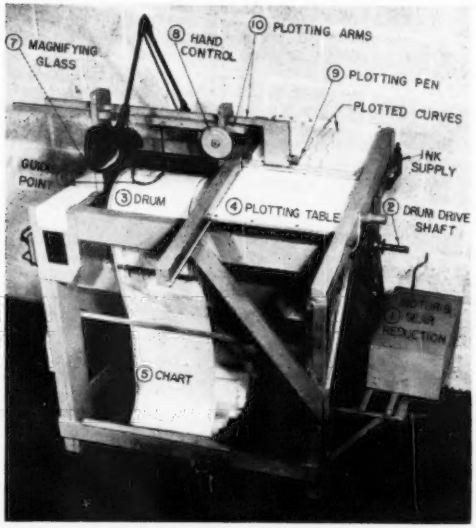
Without the use of the plotting machine, an operator would normally require at least 3 man-hours to plot the record of one thermocouple printing every 8 min for the 70-hr test. In addition, the use of the machine eliminates much of the drudgery of the hand-plotting operation.

The machine operates as follows: An electric motor is connected to the drum drive (2) (Fig. 1) through a gear-reduction system (1). As the drum (3) turns, a pinion gear on the drive shaft through the drum meshes with a rack gear that is fastened to the plotting table (4). As the chart (5) moves over the drum, the operator follows the point to be plotted with a guide point (6) by observing through the magnifying glass (7). The guide point is adjusted laterally with the hand control (8). The horizontal motion of the guide point is transferred to the plotting pen (9) through the plotting arms (10). The chart is placed over the drum and is fastened together as an endless belt. When the records for one point of the potentiometer have been plotted, it is only necessary to re-orientate the machine and continue by plotting the records for the next point. The temperature scale and the time base may be adjusted to suit individual needs.

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

The authors: U. F. EARP and V. H. BAKER, associate agricultural engineers, Virginia Agricultural Experiment Station, Blacksburg, Va.

AUTHORS' NOTE: The contributions of P. E. Larosa and J. P. R. Cristel, formerly graduate students in agricultural engineering, Virginia Polytechnic Institute, in developing the first model of this machine, and the assistance of Roy B. Davis, Jr., is gratefully acknowledged.



Machine developed by Virginia agricultural engineers for plotting the multiple-point potentiometer chart

Long-Time Performance of Draintile

(Continued from page 100)

from 18 to 34 years with depths of cover ranging from 0.8 to 2.5 ft seldom showed deterioration that would be presumed to have occurred. The letters and numerals in parentheses shown in Table 3 are the installation designations used in Table 2. At installation 8, where the tile had been installed for 31 yr with a cover of 1.5 ft of muck, they were all in good condition with an average absorption of 36.7 per cent as shown in Table 2. In the 1930 laboratory tests tile taken from stock pile at the same manufacturing plant had an average absorption of 31.6 per cent and failed after but eight freezing and thawing cycles. Only those with an absorption which did not exceed 15.1 per cent met the requirement of 36 cycles for standard draintile. Comparable situations varying only in degree were found at other of the surface-clay tile installations.

The evidence seems to warrant the assumption that draintile with fairly high absorption are more satisfactory in service than would be predicted from tests made in the laboratory.

CAUTION

It should be kept in mind that high absorption clay products are rarely high strength products. This is important in the drainage field as the present trend is to install tile relatively deep in machine dug ditches considerably wider than those formerly dug by hand. Both of these conditions materially increase the static loads on the tile, necessitating strong tile in order that cracking in the trenches may be reduced to a minimum. Furthermore, the use of heavier farm machinery than formerly has increased the superimposed load factor. In keeping with good engineering practice, the emphasis, therefore, is certain to be toward a demand for stronger tile. Fortunately, use of stronger tile will almost automatically bring about use of tile lower in absorption and, in turn, higher in frost resistance.

AUTHORS' NOTE: The authors are indebted to C. L. Larson of the division of agricultural engineering, University of Minnesota, and to the following part-time student assistants for collecting the tile from the field installations and for making the many laboratory tests: O. W. Rye, D. W. Hubbel, and Boyd Forrest. The authors are obligated to Robert Chen for assistance in making the laboratory tests and in the preparation of this report. The authors appreciate the many kindnesses extended by the landowners and occupants of the farms from which tile were taken for the tests. Without exception, cooperation was of the highest order.

Looking Ahead

IF WE are to preserve our system of private venture capital against its enemies, we must do so by continued and increased proof of its advantages over any other system. That can only be done through our products and our services. And every product, and many of our services, begin on the drafting board of the engineer.—Gen. L. H. Campbell, executive vice-president, International Harvester Co., in *Midwest Engineer* for January, 1951.

Basic Behavior at Freezing and Thawing of Six Foods

By John E. Nicholas and John S. Perry
MEMBER A.S.A.E. ASSOCIATE MEMBER A.S.A.E.

IN A former study of the freezing rates of certain foods(1)* it was observed that all products go through three successive and distinct phases of cooling. In a later study, an unusual phenomenon, the appearance of eutectic points in cooling curves, was noted in an experimental study on frozen fruit pies (2). This behavior was different from that previously noted in experiments with other foods, especially prior to freezing.

Although repeated, later experimentation yielded data which substantiated the above observation, a reasonable explanation for this anomaly was not apparent. Neither was it conceivable that this phenomenon may have eluded the many investigators during their studies in the freezing of products under the variety of conditions. Consequently additional experiments were carried out in hopes of obtaining some explanation or reason which might be applied to this apparently unusual occurrence.

The Three Stages. The three stages through which food passes are precooling, freezing or crystallizing, and subcooling to very nearly the temperature of the freezing environment in which the product is ultimately stored. Vegetables or fruits in their natural states have large water contents and may be considered mixtures of relatively homogeneous substances. In contrast, freshly prepared food products, whether cooked or uncooked, are combinations of mixtures of soluble starches, sugars, fats, salts, vitamins and other materials, and their behavior during cooling and subsequent freezing may be quite different.

In a freezing study of pies made from fresh cherries, raspberries, and blueberries, subcooling was followed by a rise in temperature presumably due to release of the heat of fusion during crystallization of sugars or other dissolved materials. Behavior of this kind characterized the process as various parts of the pies solidified. This action is of some scientific interest (3) and may have practical application where large quantities of foods of this kind are prepared and frozen for storage.

Homogeneous and Heterogeneous Systems. A system is said to be homogeneous when it is uniform throughout its whole extent and possesses in every part, identical physical properties and chemical composition (4). A heterogeneous system consists of parts having different physical properties and possibly different chemical properties. Thus a system consisting of a mixture of salts, sugars and water is a mixture corresponding to the contents of fresh fruits and vegetables. Each part can be considered in itself homogeneous and separate from the other parts.

The system as a whole, however, is heterogeneous, since it contains solids, liquids and possibly aromas in the form of gases. The homogeneous, physically distinct parts of a heterogeneous system are called phases. In a fruit or vegetable system, for example, the juices are in the liquid phase. Each phase has its own characteristic vapor pressure which changes in a definite way when the temperature is raised or lowered.

Thermal Analysis. The process of solidification, freezing or crystallization is a physical change involving the appearance or disappearance of a phase attained by the removal of heat, or accompanied by the evolution of heat.

The initial and final solidification temperatures (thermal analysis) of a mixture of two or more substances may be most easily determined by means of thermocouples. The practical determination of equilibrium is found by plotting the cooling curve of the mixture. Procedures used in this study employed thermocouples to measure rates of cooling.

Freezing Point of a Mixture. A eutectic point on the cooling curve of a mixture indicates the temperature and composition of the system when certain components crystallize out simultaneously. Several eutectic points may occur in the freezing process, depending on concentration percentages and number of components in the mixture.

When a component or components crystallize out, the process is accompanied by the evolution of heat, indicated by a rise in temperature. With the appearance of the first solid phase, the cooling curve exhibits a break or "arrest." As more and more of the solids separate, the composition of the mixture changes and crystallization again may be accompanied by sufficient evolution of heat to cause a "second arrest." With very complex mixtures, several arrests may be noted.

Freezing. In the experimental procedure followed in the studies herein reported, the freezing technique was reduced to the simplest form. Only a single berry, bean or pea was frozen at a time, each unit being fully exposed to the freezing environment. Each individual fruit or vegetable was weighed to a fraction of a milligram before and after the freezing process. The capacity of the refrigeration system was infinitely large compared to the quantity of the product, so that the effect of the freezing would be negligible on the temperature of the equipment. To obtain temperatures a thermocouple made of No. 30, copper-constantan, enamel-covered wire having a relatively small heat capacity was inserted into the approximate geometric center of the mass of the product to be frozen. During the precooling, freezing and subcooling processes, the readings were consecutively recorded at one-minute intervals. This was very important since the phenomenon under observation is a rapid change. A longer interval between readings might allow points of arrest or "eutectic" to be missed.

A simple device made of No. 18 copper wire formed a frame from which the fruit or vegetable units were easily suspended by nylon threads. This method permitted the products to literally "hang" in the air approximately 3 in from the nearest freezer surface. All freezing was carried on without mechanical air motion or contact with the freezer coils or plates. It is possible that the heat transfer from the products to the low-temperature environment was accomplished by radiation and convection.

Thawing. After a product had very nearly reached the freezing temperature environment, it was removed from the freezer. The whole unit consisting of product, suspension device and thermo-couple system was placed in the prevailing laboratory ambient which generally varied between 70 and 80F. Thawing rates were recorded at intervals similar to those of freezing.

Since the fruit or vegetable for the short interval was at a temperature lower than the dew point of the moisture in the ambient, it soon became covered with frost. In subsequent warming, the frost gradually melted and collected as a drop of water; in the case of the raspberry several drops formed consecutively.

Experimental Evidence — Eutectic Temperature. The initial temperatures of the fresh strawberry, Fig. 1, and of the low temperature air in which it was placed to freeze were 73 and −21.3 F, respectively. Cooling of the fruit was accomplished gradually, and in 9.5 min it had subcooled to 24.3 F, apparently to a eutectic point; for the temperature rose almost immediately to 29.3 F and remained relatively constant for the next 10 min, when it gradually dropped. After 37 min it attained 26 F, indicating that most of the solubles had

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The authors: JOHN E. NICHOLAS and JOHN S. PERRY, respectively, professor of agricultural engineering and instructor in agricultural engineering, Pennsylvania State College, State College, Pa.

*Numbers in parentheses refer to the appended references.

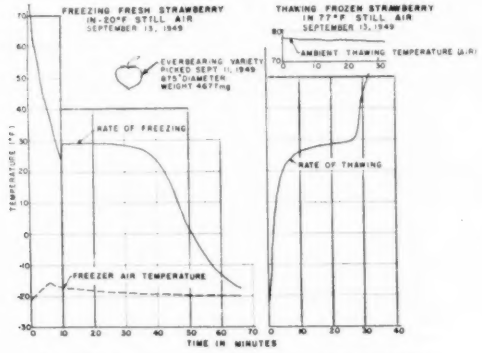

Fig. 1 The freezing and thawing rate of a fresh strawberry

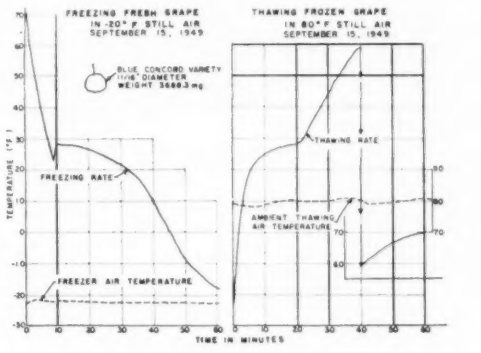

Fig. 2 Freezing and thawing rate of a concord grape

crystallized, after which the cooling was more rapid. The temperature of the strawberry at the end of one hour was –13.8 F and that of the freezing air –19.9 F. Five minutes later, the respective temperatures were found to be –17.5 and –20.1 F.

Just before the strawberry was removed from the freezer, its lowest temperature was –20.8 F, attained during 1 hr and 20 min in the freezing environment.

Upon its removal into a 77 F ambient, it warmed to plus 20.8 F in 5 min, a rise of 40 deg, and at the end of 10 min, to 26 F, the temperature very gradually rising and the fruit decrystallizing. When the first stages of decrystallization appeared complete, a very rapid rise in temperature was noted.

In the thawing process there appeared to be no temperature variation which corresponded to the eutectic or subcooled temperature noted (plus 24.3 F) during the freezing process.

Grape. The characteristic freezing and thawing curves for the Concord grape, Fig. 2, are quite similar to those of the strawberry. The initial temperatures of the grape and the freezing air were 74.9 and –22.8 F, respectively. After 9 min in the freezer the grape had subcooled to 23.1 F. Almost immediately its temperature rose to 28.3 F after which the grape again gradually cooled. At the end of 20 min it was down to 26.5 F when it began to cool more rapidly. After 30 min its temperature was 21.8 F. It had subcooled to –17.6 F at the end of one hour, when the freezing air temperature was at –22.8 F, the same as at the beginning of test.

The apparent crystallizing temperature for the grape was noted to be approximately 28.3 F. Not until the temperature reached 20 F at the end of 31 min were the largest portions of the solubles solidified, after which the rate of temperature drop became more rapid.

The interval from the time the grape was placed to freeze until removed for thawing was 3 hr and 48 min; during this time it was found to have lost 5.3 mg in weight and its temperature just before removal was –22.8 F.

Six minutes after removal it had warmed to 20.1 F and 4 min later was up to 25.2 F at which time decrystallization appeared to begin. At the end of 21 min with the temperature at 28.8 F, this seemed complete as the temperature once more rose rapidly each succeeding minute.

As the grape thawed, as in the case of the strawberry, no eutectic point was noted.

Raspberry. Because of a very late frost in the fall of 1949, a fine crop of "Indian Summer" variety raspberries became available for experimentation.

The freezing and thawing rates for the raspberry, Fig. 3, have been made at two freezing temperatures, –22 and 6 F.

It was singularly interesting that in one hour about one per cent loss in weight occurred when a fresh raspberry was exposed to room temperature without protection. Less than one per cent loss in weight generally took place in one hour when a raspberry was frozen without protection. This is a reasonable expectation.

The initial temperature of the raspberry frozen in –22 F air was 75.5 F, it measured 11/16 in in diameter, and it weighed 2874 mg. After 8¾ min, it had subcooled to 20.6 F while 15 sec later it had warmed to 29.6 F.

The initial temperature of the raspberry frozen in plus 6 F air was 68.8 F, it measured ⅞ in in diameter and it weighed 4105 mg. After 15 min, it had subcooled to 21.1 F, but it required 3 min to warm to 29.6 F.

The eutectic temperature in these two cases was found to be 20.6 F.

At the lower temperature (–22 F) the largest percentage of crystallization appeared complete at the end of 25 min and at 25.5 F, while at the higher temperature 55 min were required to develop this phenomenon.

Only the thawing temperature of raspberry frozen at –22 F are shown in Fig. 3. Placed in room temperature of 72 F it warmed from –23 to 22 F in 5 min and reached 27.8 F in 5 additional minutes. Decrystallization appeared to begin at the end of 6½ min and at a temperature of 25 F. The temperature slowly rose until decrystallization appeared complete at 30.5 F, at the end of 20 min.

The eutectic point for the raspberry for both freezing temperatures were lower than for the strawberry or grape.

Plum — German Prune. The characteristic freezing and thawing rates of a whole and of a quarter section of plum are illustrated in Figs. 4 and 5, both being frozen at –22 F and thawed at 75 F.

The quarter section cooled from 70.3 to 21.1 F in 11.5 min

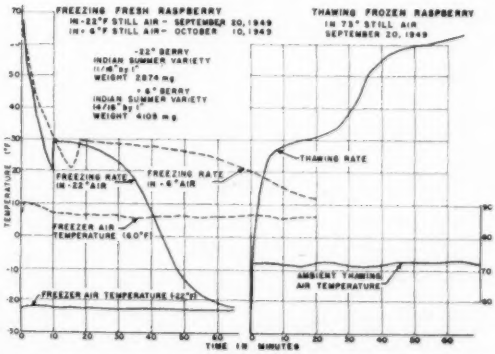

Fig. 3 The freezing and thawing rate of a raspberry. The effect of delayed freezing at plus 6 F as compared to —22 F freezing temperature is shown

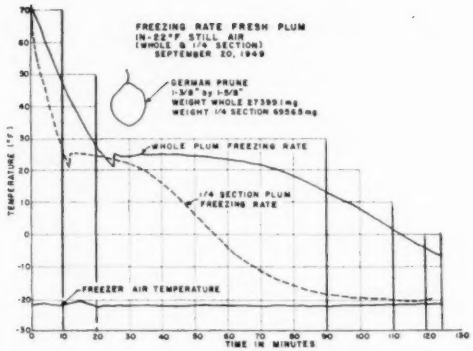

Fig. 4 Freezing rate of a fresh plum (German Prune) showing the effect of size — one-fourth section compared to whole plum on freezing rate

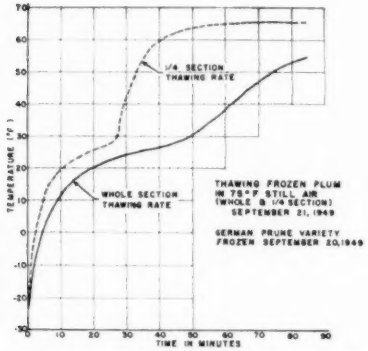

Fig. 5 The thawing rate of a one-fourth section and whole frozen plum in 75 F ambient

and warmed to 25.4 F in the next 30 sec when it continued to pass through the zone of crystallization. Eighteen minutes later, a temperature of 22 F was attained and most of the solubles had solidified. With continued freezing, the fruit temperature fell at an increasing rate.

The whole plum cooled from 74.1 to 21.5 F in 25 min, then warmed to 24.9 F in the next 30 sec; continued to crystallize, until a temperature of 22 F was reached at the 65-min interval; again the continued low temperature began to fall at an increasing rate.

The indicated freezing or crystallizing temperature for the plum (at stage of maturity used) appears to be 25 F, and the zone of crystal formation lies between 25 and 22 F.

The characteristic thawing curves for the quarter section and whole plum are similar to other fruits, Fig. 5.

The effect of mass or larger heat capacity is indicated.

Lima Bean. The stage of maturity of a fruit or vegetable is apparently an indication of the temperature at which it will begin to freeze. This probably indicates the percentage concentration of the salts or sugars in its composition.

A relatively mature lima bean (Fordhook) appears to freeze at a higher temperature than a greener bean of the same variety, Fig. 6.

The more mature lima cooled from 60.3 to 29.4 F in 5 min, showing no visible arrest or eutectic point. The crystallization continued between 29 and 27 F for 12 min, or to the 17-min interval, after which the temperature fell very rapidly, indicating that the zone of maximum crystal formation had been completed.

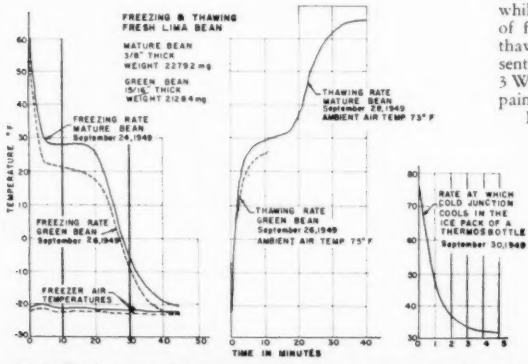

Fig. 6 The freezing and thawing rates of a green and mature lima bean. The effect of maturity or a difference in solubles seems indicated

A relatively green lima bean subcooled from 62.1 to 22 F in 5½ min, and gradually crystallized between 22 and 19 F. The zone of maximum crystal formation appeared complete at the end of the 18 min and the increasing rate of temperature decline again was observed.

The thawing temperatures followed the characteristic pattern of the fruits. In this case the lima warmed from −22.6 to 25.2 F in the first 5 min; from 25.2 to 29.4 F in the next 5 min, and completed decrystallization in the third 5 min at 31 F.

Peas. This study raised another interesting phase in food freezing. Was the heat transferred from the products to the freezer plates by convection, by radiation, or both? Was it possible to determine which of these two methods played a predominating role in the heat-transfer process?

To provide, perhaps in part, a possible explanation for these questions, tests were made in which single units of products were frozen in 2-by-2-in hollow cubes made from a 20-gage sheet aluminum. One cube was painted black internally, and the other was unpainted, permitting normal reflecting power from all sides. The painted internal walls presumably had the powers of absorption of radiant energy of a black body; hence, the products frozen inside the painted cube might show a measurable difference in rate of heat transfer from that of products frozen in the unpainted cube.

Peas were the product selected for the test, primarily because of ease in handling.

Simple wire chairs or supports permitted the cubes to be similarly placed equidistant between two horizontal evaporators spaced 12 in apart. Individual peas were suspended in the approximate geometric center of the respective cubes, with a thermocouple located in each for temperature measurement, while an additional couple was used to obtain the temperature of freezing air. No air motion was used. The freezing and thawing rates of the peas, under these conditions are presented in Fig. 7. The designations 1 B and 2 B, and 2 W and 3 W refer to individual peas frozen in the black and unpainted cubes respectively.

In one of the trials (left chart) pea 1 B cooled from 64.6 to 17.6 F in 5 min and 25 sec (black cube) and pea 2 W cooled from 65.9 to 11.9 F in 7 min (white cube). Pea 1 B rose in temperature from a eutectic point of 17.6 to 26.1 F in 35 sec, while pea 2 W rose in a similar way from 11.9 to 27 F in the succeeding minute. The zone of maximum crystal formation in both cases appears to be between 27 and 25 F and seems to have been complete at the end of 16 min followed by accelerated cooling to the air freezing temperature.

The thawing curve for peas was characteristically the same as for the other products reported. No measurable differences in heat transfer were found under the conditions of this test; therefore, whether the heat transfer was by radiation or convection remained undetermined.

SUMMARY

1 In the freezing of a fresh fruit or vegetable the cooling curve will show a rise in temperature from an arrest point presumably because of crystallization of sugars, or other dissolved substances in the juices.

2 Characteristic freezing and thawing rates were recorded for raspberries, strawberries, grapes, plums, lima beans and peas.

3 Unusual behavior on the part of fruits and vegetables before crystallization was noted.

4 All products supercooled to much lower temperatures than those at which freezing began.

5 The lowest point of arrest noted was 11.9 F found in a pea, which subsequently rose to 27 F before cooling to the freezing air temperature.

6 After an arrest or eutectic point was reached, the temperature to which the product warmed appears to indicate its freezing temperature.

7 These studies show that freezing of unwrapped products exposed to low temperatures without air motion is rapid. This principle may have industrial application when large quantities of foods are to be frozen.

8 When soluble materials are frozen out of solution, the crystallization process is exothermic as indicated by a rise in temperature.

9 From the studies of this series it was not possible to differentiate freezing by convection from freezing by radiation (Fig. 7).

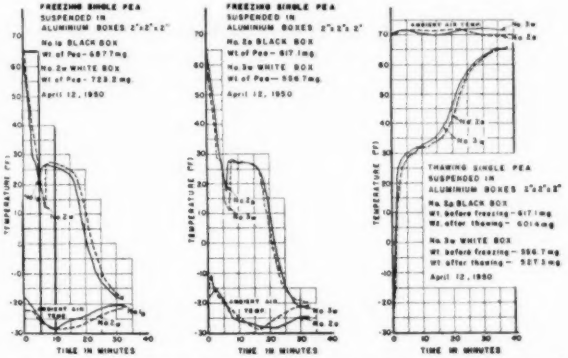

Fig. 7 The freezing and thawing rates of single peas suspended in blackened and unblackened aluminum boxes

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Determination of Water in Some Dehydrated Foods

By Benjamin Makower

MOISTURE determination is probably one of the most important and most widely used analytical measurements in the processing and testing of food products. It is of economic importance both to the consumer and to the food technologist. To the technologist, the moisture content is frequently an index of stability and quality of food, while to the consumer it may serve as a measure of quantity as well as a measure of quality.

The methods used for the determination of moisture in dehydrated foods have been divided into two classes, the direct and the indirect. The indirect methods, such as the electrical ones, must be calibrated in terms of the direct methods.

The most common direct methods are the oven, the distillation, and the Fischer methods. They can be made precise by careful standardization of the experimental procedures; their accuracy can be assured only by calibration against some accurate reference method.

Some of the common factors that control the accuracy of these direct methods are incomplete removal of water, thermal decomposition, volatility of non-aqueous components, and certain side reactions, such as oxidation and non-specificity of the Fischer reagent.

A number of investigations describing different reference methods have been reviewed. They include drying to constant weight in vacuo at room temperature over a good desiccant, the redrying procedure (oven drying), the lyophilization procedure, distillation with organic solvents, the reversibility procedure (oven drying), and a modification of the Fischer method.

None of these reference methods can be given an unqualified recommendation as being the most practical and suitable for all foods. The room-temperature-drying method is prohibitively long. The redrying and reversibility procedures are rather laborious and time consuming. The distillation method cannot ordinarily be used for calibration, because it does not usually yield a definite end point. The lyophilization procedure appears to be the most direct and convenient calibration method for materials, such as vegetables, that do not contain much non-aqueous volatile matter. For a material rich in these volatiles a modification of the procedure has been suggested whereby the volatiles could be isolated and determined separately.

The extraction of water at room temperature as a procedure for the calibration of the Fischer method requires further verification, because the reagent is not specific for water. It would be desirable to compare this calibration procedure with another. In general, agreement in the results of two or more independent calibration procedures might be used as a criterion of the attainment of accuracy.

It appears that each particular food must be investigated separately to determine the most advantageous and expeditious method of calibration. Furthermore, the accuracy of a given calibration method can be expressed only in reference to the particular food material under investigation and not for a method in general.

The choice of a particular method for routine measurements of moisture will depend on the nature of the food and the requirements of the analysis. The direct methods are generally more suitable where high precision or accuracy are desired and speed is not important. The indirect methods are usally applicable when speed is essential, but high precision is not required.

The advantages of vapor pressure as an index of moisture are discussed. At the present time very few vapor-pressure data are available for foods. It would be of great interest to measure vapor pressure concurrently with the moisture content in order to determine the usefulness of the vapor pressure in studies on the stability of dehydrated foods.

This is an abstract of a paper presented at the annual meeting of the American Society of Agricultural Engineers at East Lansing, Mich., June, 1949, as a contribution of the Rural Electric Division.

The author: BENJAMIN MAKOWER, in charge of raw material section, fruit processing div., Western Regional Research Laboratory, U.S. Department of Agriculture, Albany, Calif.

Ventilation of Grain Storages

By Otto F. Theimer

ACCORDING to experiments conducted by Dr. Kurt Seidel, Berlin, 1 kg of grain with a moisture content between 14 and 15 per cent produces the quantities of carbon dioxide during 24 hr at various temperatures shown in Table 1. However, respiration of grain is greater at higher percentages of moisture. For example, at 18C, the respiration, or production of carbon dioxide per kilogram of grain within 24 hr at different percentages of moisture is shown in Table 2.

TABLE 1

Temperature, deg C	Respiration, mg CO_2
18	1.4
30	7.5
40	20.0
52	240.0

TABLE 2

Moisture Content, per cent	Respiration, mg CO_2
11	0.35
14-15	1.40
17	123
20.5	359
33	2000

Moisture Content of Grain. Moisture contents of grain vary widely with locations and climatic conditions. In central Europe (Germany, Czechoslovakia, Austria) the average content of moisture in grain amounts to 15 to 16 per cent; in damp seasons it may rise to 19 per cent more. In the British Isles, due to climatic conditions, the moisture content may even climb to 24 per cent in wheat and barley. In other countries, however, with drier weather during harvest time, such as southeastern Europe, (Hungary, Roumania, southern Russia) and, above all, the Middle West of the United States and Canada, grain is quite dry, within 14 per cent, or even containing only 11 per cent moisture. Such grain is considered dry enough for safe storage, because respiration is practically negligible.

At 15 per cent moisture, however, respiration is suddenly released (Table 2). Such grain with more than 15 or 16 per cent moisture is called damp grain and cannot be stored in closed bins of grain elevators. It has to be treated carefully on flat storage space, or dried down to 14 per cent by artificial heat driers, a process which is quite expensive; or with a less costly method, now common practice in central Europe. This latter method keeps damp grain cool by forced-air circulation in bins of especially designed grain elevators, whereby also a moderate drying effect can be achieved, provided certain rules for ventilation are observed.

Equilibrium Relationship. Relative humidity of air is of great importance to grain storage. After some time in storage, grain will adjust itself to the humidity of surrounding air. There is a certain equilibrium relationship between the moisture content of grain and the relative humidity of air, according to Dr. Seidel (Table 3).

TABLE 3

Relative humidity of air, per cent	Moisture content of grain, per cent
5	3.8
18	7.1
45	11.4
55	12.8
65	14.2
75	15.5
81	16.5
87	18.6

The author has developed the accompanying graphical chart to determine optimum atmospheric conditions for safe ventilation, a practical help to grain elevator operators, which is time saving and foolproof.

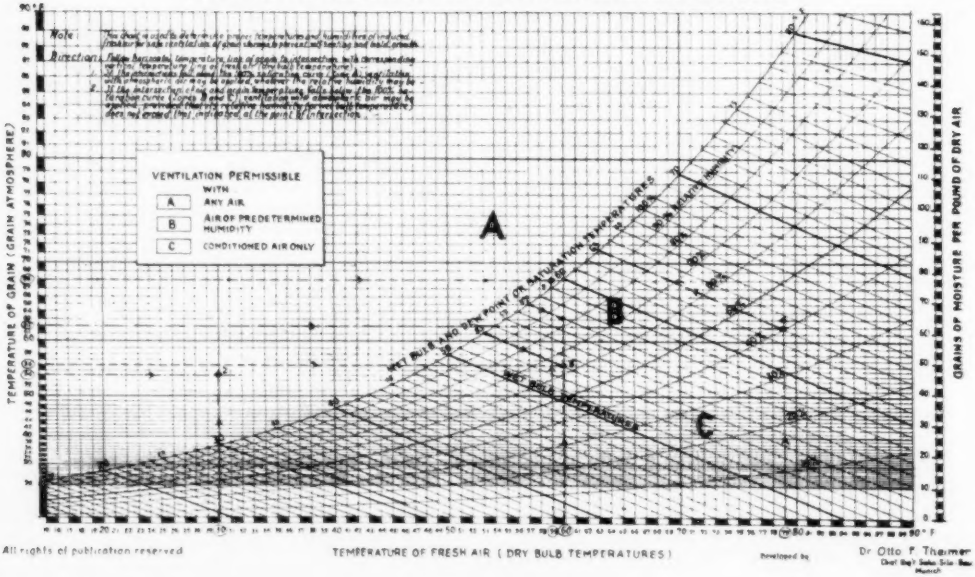
This chart is based on the stipulation that waste air, after passing through the grain, shall contain only 75 per cent relative humidity or less, not taking into account any moisture which it may absorb from the grain. The chart has been so arranged that the grain-temperature lines in their relation to the saturation curve of the diagram indicate the permissible limits of relative air humidity for safe ventilation.

The horizontal lines of the chart denote the usual grain temperatures ranging from 20 to (Continued on page 108)

Abstract of a paper prepared expressly for AGRICULTURAL ENGINEERING.

The author: OTTO F. THEIMER, chief engineer, Suka-Silo Ban, Munich, Germany.

PSYCHROMETRIC CHART FOR VENTILATED GRAIN STORAGE



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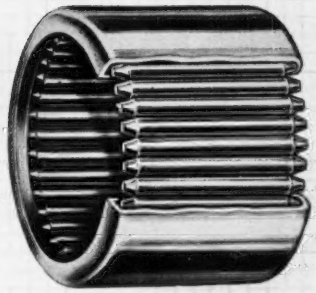
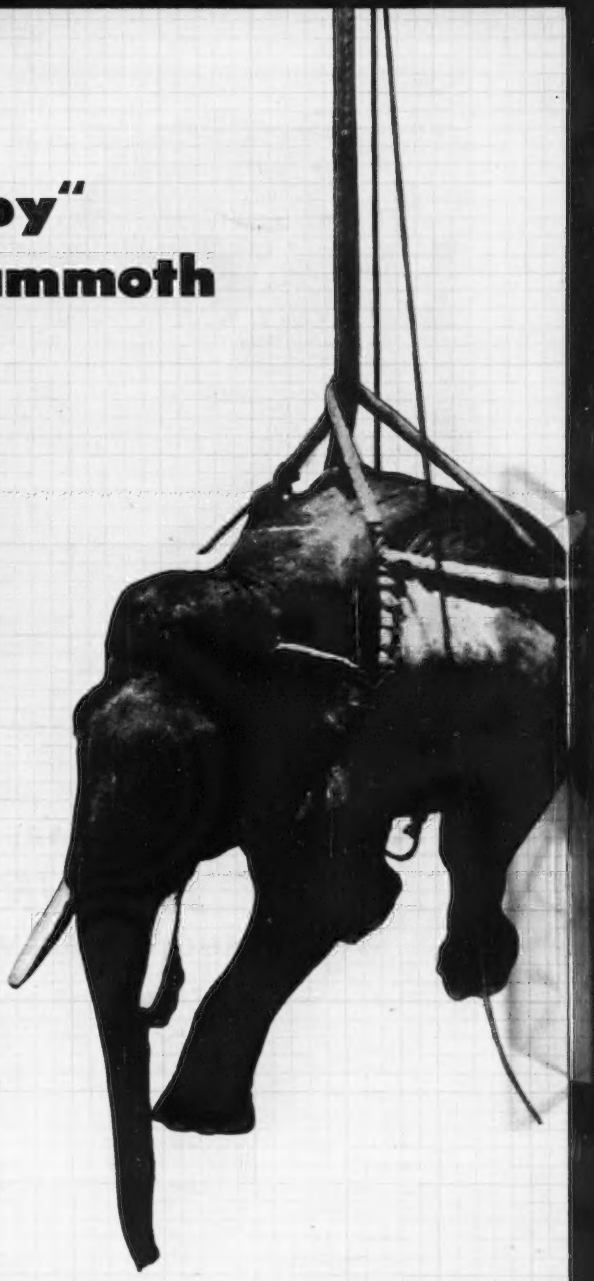
developed by Dr Otto F. Theimer

how to "baby" a mammoth





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Grain Storages

(Continued from page 106)

90 F. The vertical lines represent the normal temperatures of the atmosphere from 15 to 90 F, or dry-bulb temperatures, with values indicated on the lower edge of the chart. Wet-bulb temperatures are represented by oblique lines with values indicated at their intersection with the curved line marked "Wet Bulb and Dew Point or Saturation Temperatures." The curves in the chart indicate the relation of the two variables, that is, temperature of grain and temperature of fresh air, to the relative humidities of all possible air humidities from 0 to 100 per cent.

The chart is divided into 3 zones, A, B and C. Zone A being the area of the chart above the 100 per cent saturation curve; zone B, the area between the 100 and 50 per cent R.H. curves; and zone C, the area below the 50 per cent R.H. line. In order to find out which zone is indicated for proper ventilation, it is only necessary to locate point of intersection of the grain-temperature and air-temperature lines. If the intersection falls above the 100 per cent saturation curve, or in zone A, ventilation with atmospheric air may be applied, whatever the relative humidity may be. Even air with a 100 per cent R.H. may be used, because the induced air will be warmed within the grain to such an extent, that the waste air will, at most, reach a 75 per cent saturation after passing through the grain. The growth of molds will positively be prevented and grain will be safe in storage. This is always the case if the induced air is at least 8 F cooler than grain, as can be seen from the chart.

However, if the point of intersection of the grain-temperature line and the air-temperature line falls within zone B, it means that air having a certain specified relative humidity has to be used, in order to limit waste air to 75 per cent R.H. In this case, the relative humidity of the air has to be predetermined by measurement, indicated by the oblique line at the intersection point.

In cases where the intersection points fall into zone C, only preconditioned air may be used for ventilation. Air with lower relative humidity than 50 per cent is chiefly used for drying of grain and such ventilation is not the subject of the present article.

To explain the method further and to illustrate the practical use of the chart, a few examples are discussed below:

Example 1 (Autumn). Combine-harvested wheat was stored in an elevator and during autumn the temperature within the bulk of grain rose to 68 F. For cooling purposes fresh air of 59 F is available, giving a difference of 9 F. The intersection point of corre- *(Continued on page 110)*

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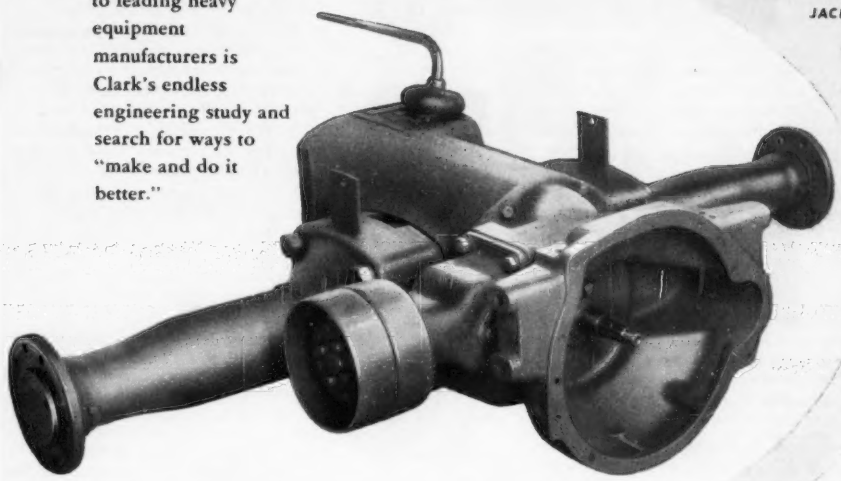

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Grain Storages

(Continued from page 108)

spreading temperature lines falls into zone A just above the 100 per cent saturation curve. Therefore, any relative humidity of the atmospheric air may be applied.

Example 2 (Winter). Given outside temperature 30F, wheat stored is still showing a temperature of 54F, giving a difference of 24F. It is very desirable to cool this wheat down to a lower temperature, say, almost to freezing point. The intersection point of corresponding temperature lines is shown to fall far into zone A. Therefore, in this case, too, ventilation with the available atmospheric air may be undertaken, whatever the relative humidity may be.

Example 3 (Spring). Given a dry-bulb temperature of fresh air of 60F and its wet-bulb temperature of 57F, oats stored in bins is found to get warmer steadily up to 56F to give a difference of 4F. Although the fresh air is warmer than the grain, it will be necessary to ventilate in order to prevent the oats from becoming musty.

According to the chart, the intersection point falls into zone B, indicating a relative humidity of 63 per cent and a wet-bulb temperature of 53F. As the wet-bulb temperature is actually 57F, ventilation may not be applied with the available atmospheric air.

Example 4 (Summer). Outside temperature is 79F. Stored grain is showing increased respiratory activities and constantly rising temperatures. At 62F grain temperature ventilation shall be applied. In this case the intersection point of temperature lines in the chart directs us to zone C, because the air is much warmer than grain for a temperature difference of 17F. For safe ventilation the air should not exceed 40 per cent in relative humidity, or the wet-bulb temperature should be at most 61F. Such air usually not being available even in summer, the grain must be transferred to another bin and mixed with cooler grain to prevent further self-heating. But also in summer, cool air may be available during the night hours, to treat such "working" grain with fresh air successfully.

General Rules for Ventilation. As can be seen from the foregoing examples, ventilation of grain should be done preferably in autumn or winter, when the outside air is cooler than the grain. Grain should be cooled to, or below, freezing point during winter months in order to restrict respiration and loss of substance to a minimum. In general, the following rules for ventilation can be safely followed:

1. At normal humidity of air, the temperature of atmospheric air must be at least 8 F lower than the temperature of grain.

2. During the warmer periods of the year, the hours after midnight should be chosen for ventilating operations.

3. On rainy and foggy days (excessive dampness of air) no ventilation should take place unless there is a difference of at least 16 F between outside air temperature and the temperature of the grain.

4. The ventilating operations should be continued until the waste air is at most 4 F warmer than fresh air.

5. In cold weather the grain should be cooled to below freezing point.

6. The temperatures of grain should be kept at a maximum of 50 F from September to May, and at a maximum of 68 F from June to August, preferably lower.

The accompanying psychrometric chart is not only of advantage in grain storages, but also to other storehouses where organic foodstuffs are stored, such as flower, bran, bread, etc. Instead of the temperature of the grain atmosphere, the temperature of the storage space has to be taken into account. By means of the chart the conditions of fresh air (temperature and relative humidity) can be determined for safe ventilation. If these conditions of the atmospheric air are strictly followed, molding of stored products will be avoided.

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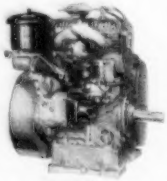

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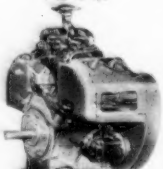

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NEWS SECTION

A.S.A.E. Meetings Calendar

February 17—MICHIGAN AREA SECTION, Grosse Pointe War Memorial Center, 32 Lake Shore Drive, Detroit, Mich.

February 26—CHICAGO SECTION, The Builder's Club, 22nd floor, 228 N. La Salle St., Chicago, Ill.

March 2—IOWA-ILLINOIS SECTION, Short Hills Country Club, East Moline, Ill.

March 23 and 24—SOUTHWEST SECTION, Grim Hotel, Texarkana, Tex.

June 18-20—ANNUAL MEETING, Rice Hotel, Houston, Tex.

August 27-29—NORTH ATLANTIC SECTION, Chalfonte-Haddon Hall, Atlantic City, N. J.

NOTE: Information on the above meetings, including copies of programs, etc., will be sent on request to A.S.A.E., St. Joseph, Michigan.

ASAE Council Elects Nine Life Members

AT ITS last meeting in December, the Council of the American Society of Agricultural Engineers elected the following members of the Society to life membership, these members having fulfilled the requirements of the Society's By-Laws for such membership:

Wallace Ashby, head, farm building and rural housing division (BPISAE), U.S. Department of Agriculture.

R. U. Blasingame, head, agricultural engineering department, Pennsylvania State College.

Deane G. Carter, professor of farm structures, University of Illinois.

E. V. Collins, research professor of agricultural engineering, Iowa Agricultural Experiment Station.

George W. Iverson, sales manager, Industrial division, J. I. Case Company.

E. W. Lehmann, head, agricultural engineering department, University of Illinois.

G. W. McCuen, head, agricultural engineering department, Ohio State University.

C. K. Shedd, senior agricultural engineer (BPISAE), U.S. Department of Agriculture.

O. W. Sjogren, special representative, John Deere Killifer Company.

Thor Christensen New Chairman of Pacific Coast Section

THOR W. Christensen, assistant to the manager of rural electric sales, Pacific Gas and Electric Company, was elected chairman of the Pacific Coast Section of the American Society of Agricultural Engineers at the Section's 29th annual meeting held January 26 and 27 in Los Angeles. He succeeds Clarence T. Rasmussen, chief engineer, John Deere Killifer Company.

Two other officers elected at the meeting include the new vice-chairman of the Section, Henry Karrer, engineer-manager, Fresno Irrigation District, Fresno, Calif., and Walter W. Weir, drainage engineer, University of California, who was re-elected secretary-treasurer. M. R. Huberty, University of California, was elected a member of the executive committee.

Technical sessions on the first day of the meeting were held in the auditorium of the Sunskist Building in Los Angeles. The forenoon program opened with a talk by E. B. Rider, senior engineer of the Metropolitan Water District, on the role of the district in augmenting southern California's water supply. M. E. Hamilton, chief engineer, Stockton Works, J. I. Case Co., reported progress on the standardization of hydraulic controls on farm tractors, with particular reference to tractors of 35 dhp and larger. Techniques for drainage investigations, reporting in particular the cooperative study of four different agencies in the Coachella Valley of California, was the subject of a talk by A. F. Pillsbury, associate professor of irrigation, University of California at Los Angeles. James N. Luthin, University of California, Davis, presented a technical paper on the numerical analyses of flow through aquifers into wells.

The afternoon program opened with a paper by Samuel A. Hart, junior irrigation engineer, University of California at Los Angeles on the principles of greenhouse design. This was followed by a review of orchard heater development by A. S. Leonard, agricultural engineering division, University of California at Davis. J. R. Tavernetti, agricultural engineering division, University of California, and B. B. Ewing, Farm machinery division (BPISAE) U.S. Department of Agriculture, reported on the joint project of the two agencies with particular reference to factors affecting the machine picking of cotton. J. Biale, University of California, discussed the subject of fruit physiology in relation to storage. This was followed by a talk by H. B. Walker, professor of agricultural engineering,

(*Continued on page 114*)

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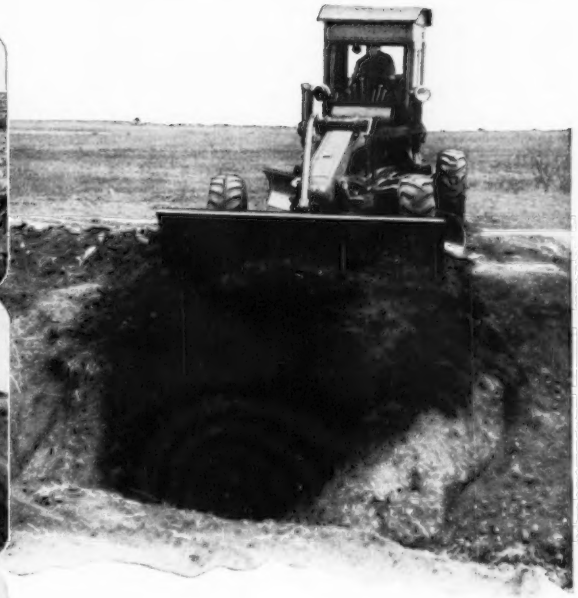

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UNITED STATES STEEL

 (Continued from page 112)

ing the problem of segregating lemons by color. John B. Powers, University of California, was the last speaker at the session and discussed electronic determination of color in lemons. The technical session was followed by a business meeting of the section, including the election of officers.

The annual Section dinner was held in the evening of January 26 at the Rodger Young Auditorium, with Clarence T. Rasmussen, chairman of the Section, presiding. The feature of the dinner program was an illustrated talk by R. Earl Storie, soil technologist in charge of soil surveys, University of California, Berkeley, based on his experience as a member of the United Nations Mission of Technical Assistance to Bolivia.

The program on January 27 was devoted exclusively to a tour of the new engineering buildings on the campus of the University of California at Los Angeles, including inspections of many of the interesting projects being conducted by the College of Engineering.

Michigan Section Winter Meeting

THE Michigan Area Section of the American Society of Agricultural Engineers will hold its winter meeting on February 17 at the Grosse Pointe Memorial Center, Grosse Pointe, Michigan. The meeting will open at 10:15 a.m. with a report on the activities of the National Institute of Agricultural Engineering in England, by Peter Hebblethwaite, English agricultural engineering graduate student of Michigan State College. The second speaker on the morning program will be R. F. Weber, district sales representative, The Deming Company, who will discuss pumps for agricultural use. Following lunch, Mr. Tremblay, Industrial Photographic Service, will treat the group to a very interesting presentation on the use of high-speed movies to study rapid motion. The concluding paper on the program will be on frost control with wind, heat, and water by E. H. Kidder and C. M. Hansen, associate and assistant professor, respectively, of agricultural engineering, Michigan State College.

Brown Addresses Washington Section

AT ITS regular monthly meeting, January 12, the Washington (D.C.) Section of the American Society of Agricultural Engineers was addressed by Carl B. Brown, Soil Conservation Service. His presentation was of particularly current interest as Mr. Brown has been serving as a member of President Truman's Water Resources Policy Commission. The serious nature and advisability of a coordinated approach to the conservation and utilization of our national water resources was pointed out. An introduction to this problem and a summary of the work which had been accomplished by the Commission showed the scope of integration of ideas among the groups concerned with the varied aspects of our water resources. About 42 members and visitors were in attendance at the meeting.

Committee Activities

A NEW ASAE subcommittee — Subcommittee on Drainage Equipment — to study the requirements and effectiveness of equipment used for drainage work, is being set up by the Committee on Drainage (Soil and Water Division), of which John G. Sutton is chairman. It is intended that this subcommittee, of which Irwin L. Saveson, SCS research project supervisor at Baton Rouge, La., is chairman, will bring together men primarily interested in the development of equipment and those engaged in drainage work.

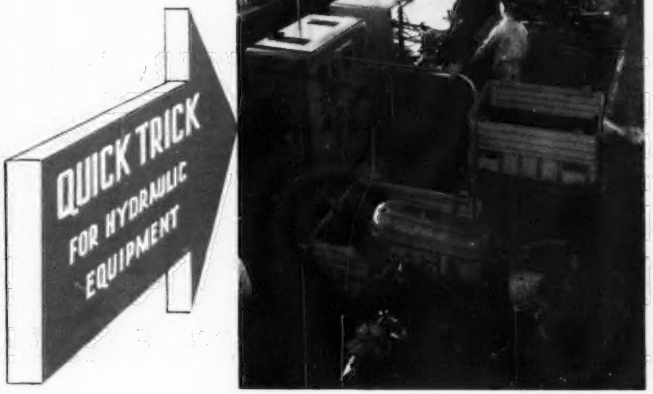
Florida to Have Professional AE Curriculum

ACCORDING to word received from Frazier Rogers, head, department of agricultural engineering, University of Florida, Gainesville, a professional curriculum in agricultural engineering was recently approfessional curriculuma in agricultural engineering was recently approved by the senate of the University of Florida. This curriculum will be administered jointly by the college of agriculture and engineering. Students enrolled in the curriculum will register in and receive their degrees from the engineering college.

Southern Farm Equipment Manufacturers Organize

FARM equipment manufacturers from ten southeastern states recently organized as the Southern Farm Equipment Manufacturers, Inc. The mission of the new organization will be to bring about intelligent cooperation and sharing of ideas concerning modern metal-working methods among the participating organizations. It will also enable them to recognize and do something about the fact that all members of the farm equipment manufacturing industry in the South must be strengthened in order for the industry to prosper as a whole.

The following officers were elected for the coming year: President, J. T. Cash, vice-president and treasurer, Knox Metal Products, Inc., Thomson, Ga.; vice-president and treasurer, E. C. Gibson, vice-president and general manager, Southern Iron and Equipment Co., Atlanta, Ga.; and executive vice-president, E. R. Rushin, product engineer, Atlanta Steel Co., Atlanta, Ga.



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15 versions of the famous FLOW-TING Spring Hydraulic Seat are now available to fit 95% of all tractor makes and models—as well as many self-propelled combines and earth-moving units.

SPECIFIC DESIGNS FOR ANY MACHINE

Knoedler can develop a FLOW-TING seat designed to fit most any tractor or implement — large or small, present or proposed. This engineering cooperation is available without cost or obligation.

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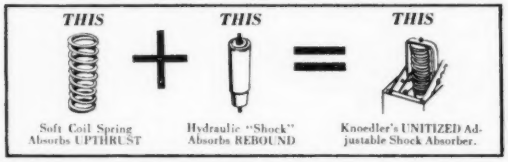
Despite wide variation in appearance and construction, all Knoedler seats operate on the "unitized" spring-hydraulic assembly proven by the auto industry to be the last "ride control" principle so far developed. All models provide instant adjustment to "tailor" the ride to driver's weight or ground conditions.



SPRINGS ALONE AREN'T ENOUGH!

It takes *both* springs and hydraulic shock absorber action to provide effective ride control. The auto industry proved that years ago. Let us show you how the Knoedler seat can be adapted to any machine where an even "floating" ride—free from shock, "see-saw" or dumping action — can contribute to operator safety & health.

Knoedler's proven Ride-Control principle can be developed for any tractor or implement design, present or proposed. Speculative engineering help available at no obligation.

Phone or write for prices, prints or specifications.

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PERSONALS OF ASAE MEMBERS

Seward H. Foote, Jr., formerly agricultural field representative in New York state for the Portland Cement Association, has recently accepted appointment as public relations representative of the Lederle Laboratories Division of the American Cyanamid Co., with headquarters at 905 Waltower Bldg., Kansas City, Mo.

Evan A. Hardy, head, department of agricultural engineering, University of Saskatchewan, will be on leave from his regular duties during the ensuing year, to assist the Government of Ceylon, at the request of the Food and Agriculture Organization of the United Nations, in the development of a new area for dry-land cereal production to stimulate the country's effort in the production of food. This activity is part of the United Nations technical assistance program in Ceylon.

C. G. Pearse, vice-president and domestic sales manager, J. I. Case Co., has been given general supervision of domestic sales of the company, succeeding W. L. Clark. Mr. Pierce has been with the Case organization since 1914, working his way up through the sales department, as salesman, general collector, assistant branch manager, branch manager, assistant sales manager, manager of domestic sles. In 1948 he was elected a vice-president of the Company.

W. J. Ridout, Jr., rural service manager of the Edison Electric Institute since 1947, has been appointed editor of *Electricity on the Farm* magazine. He succeeds the late Geo. W. Kable. Mr. Ridout graduated from Virginia Polytechnic Institute in 1939 with a BS degree in agricultural engineering. Immediately upon graduation he joined the Kentucky and West Virginia Power Co. at Pikeville, Ky., as rural service engineer, and held this position until late 1940, when he became power engineer for the East Tennessee Light and Power Co. at Bristol, Tenn. In 1941 Mr. Ridout became extension agricultural engineer in charge of rural electrification for the South Carolina Extension Service. During World War II he saw service in the Pacific as an ensign in the Navy. After being placed on inactive duty with the Navy in 1945 he joined the North Carolina Extension Service in charge of rural electrification. He was appointed rural service manager of the Edison Electric Institute in 1947.

M. J. Taup, manager, mobile products sales, Vickers, Inc., has recently been transferred from Chicago to the Detroit office of the Company with headquarters at 1400 Oakman Boulevard. While in Chicago, Mr. Taup served as the Society's representative to the National Conference on Industrial Hydraulics.

W. L. Ulich, extension agricultural engineer, A. & M. College of Texas, won the 1950 fourth-place award in the education division of the James F. Lincoln Arc Welding Foundation competition. The winners in each division received a cash award and were given the privilege of designating a scholarship to an agricultural engineering student. Mr. Ulich elected to give the scholarship provided by his award to a student at A. & M. College of Texas, which is also his alma mater. The scholarship, valued at $500, was awarded to R. C. Giesecke, a senior, at a meeting of the Texas Student Branch of ASAE. A second scholarship was also awarded to L. A. Holms, a junior student, by W. T. Gunter who won the fourth prize in the agricultural producers division of the contest. The scholarship winners were selected from students in the professional agricultural engineering curriculums, upon the basis of scholarship and general all-around character and ability.

Robert W. Whitaker, formerly instructor in farm structures, University of Illinois, recently accepted employment with the A. O. Smith Corp., Milwaukee, Wis., with whom he will be engaged in farm equipment research and development.

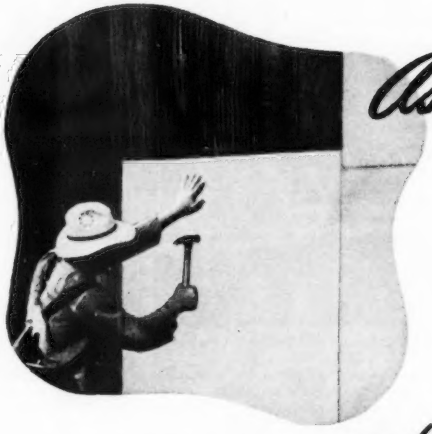
NEW BULLETINS

A Comparison of the Effectiveness of Winterized and Mud-Snow Tires on Snow and Ice. National Safety Council (Chicago, Ill.) This is a report prepared by the Council's Committee on Winter Driving Hazards. It covers test methods and results as well as conclusions. The latter indicate progress in improving the tractive performance of tires under winter conditions, but not enough so that the Committee was ready to revise its standing recommendations for winter driving safety.

Sediment Design Criteria for the Missouri Basin Loess Hills, by L. Gottschalk and Gunnar M. Brune. SCSTP 97 (October, 1950). A technical review of the problem, field studies, results, recommendations, and conclusions.

Investigation of Rock Drilling Equipment for Fence Postholes and Other Farm Uses, by Edsel J. Burkhart. Texas Engineering Experiment Station (College Station) Research Report No. 17, October, 1950. Discussion of methods and equipment for drilling postholes in rocky soils. Preliminary analysis, not supported in all cases by actual tests, is indicated to favor the power auger for soil containing loose rock; the gasoline-operated jack hammer for holes of less than 4-in diameter in medium to hard rock; and shot-bit rotary drilling for holes of 4-in diameter or larger, and 2 ft deep in medium to hard rock.

For greater fire safety on the farm ...Johns-Manville Building Materials



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STRONG AND TOUGH: Time-tested sheet material of asbestos and cement, can be used outdoors, indoors... is rodentproof, fireproof, sanitary. Saws and nails like wood, never needs preservative treatment. So flexible it can be used on curved surfaces.

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—LAST 35 YEARS PLUS! Fireproof, rotproof, weatherproof. Thousands have already been in service 35 years. No signs they won't last another 35 years or more! New American Colonial design is the most beautiful ever developed. Easy to apply.

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SUPERIOR INSULATION: Keeps farm building temperatures more uniform... helps produce more milk, more eggs, more weight per pound of feed. Easily installed, fits snugly, will not settle. And it's *fireproof* . . . you can't burn it even with a blow torch.

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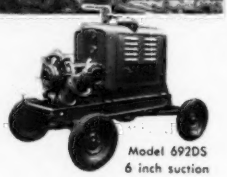
JM PRODUCTS

Marlow WATER WIZARD
SPRINKLER IRRIGATION PUMPS

. . . dependable
. . . economical
. . . easy to use



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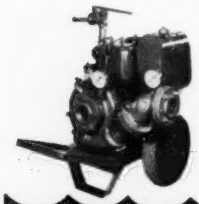
6 inch suction
and discharge

Modern design — These pumps embody the latest features for modern sprinkler irrigation. Marlow Water Wizards are new . . . designed especially for today's new pressure and capacity requirements. They will supply water dependably. They are thrifty and virtually maintenance-free in operation and are built to last for years.

Complete size range — Marlow centrifugal irrigation pumps offer a wide choice of models for *any* job. Available in 14 models, sizes 2- to 6-inch, including two models designed especially for 2- and 3-acre sprinklers. Capacities 50 to 1900 GPM; pressures 30 to 200 PSI. Gasoline and Diesel engine driven; all models may be equipped for belt drive or supplied direct coupled to electric motors. Skid mounted or with steel wheels or rubber tires.

Model 312S 3 inch
suction and discharge



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Manufacturers of Quality Pumps for Over a Quarter of a Century

Applicants for Membership

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Batchelder, Edwin L., Jr.—Farmer, 411 Exeter Rd., Hampton, N. H.

Bonnicksen, LeRoy W.—Industry fellow in agr. eng. res., Iowa Agricultural Experiment Station, Ames, Iowa. (Mail) 331 Pammel Court

Brannstrom, Arnold J.—Asst. co. supervisor (FHA), USDA. (Mail) 115 West Grand Traverse, Big Rapids, Mich.

Clement, Dean E.—Eng. service trainee, Harry Ferguson, Inc. (Mail) 1944 Edison St., Detroit 6, Mich.

Cole, John M.—Trainee, J. I. Case Co. (Mail) 2004 Belle Ave., Davenport, Iowa

Cook, Donald J.—Farm service advisor, Detroit Edison Co., Monroe, Mich.

Cook, Eldridge J.—Sales promotion dept., J. I. Case Co. (Mail) 1047 Gordon St., S. W., Atlanta, Ga.

Coy, Glenn C.—R R 1, Stryker, Ohio

Cromwell, Charles F., Jr.—Service man, W. W. Weeth "Wil-Do" Ranch Headquarters, Box 1457, Coalinga, Calif.

Cunningham, Henry, III—Trainee, Caterpillar Tractor Co., Peoria, Ill. (Mail) 118 N. Institute Place

Dav, Omar H.—Engr., product research and development, Butler Mfg. Co., 7400 East 13th, Kansas City, Mo.

Diederichs, Leonard P.—Asst. service mgr., Northwest Tractor and Equipment Co., Minneapolis, Minn. (Mail) 4926 42nd Ave., S.

Dorran, Russell N.—Advisor, Umatilla Electric Cooperative Assn. (Mail) R R 1, Helix, Ore.

Edie, Charles C.—Trainee, eng. service, Harry Ferguson, Inc. (Mail) 3525 Krafft Rd., Port Huron, Mich.

Ferguson, C. E.—Engr., line superintendent, Kay Electric Cooperative, Blackwell, Okla. (Mail) 921 S. Main St.

Filson, Russell N.—Farmer, Woodrow, Sask., Canada

Finley, Weyman E.—Service rep., Gibbs Corp., Maitland, Fla. (Mail) P O Box 281

Fisher, Howard F.—Bridge designer, Iowa State Highway Commission, Ames, Iowa. (Mail) 221 Hyland

Ford, R. F.—Fieldman in agr. eng., Canadian Dept. of Agriculture. (Mail) Agricultural Engineering Dept., Ontario Agricultural College, Guelph, Ont., Canada

Forshee, C. L.—Eng. sales, Goulds Pumps, Inc., Seneca Falls, N. Y.

Glover, John W.—Trainee, International Harvester Co., Charlotte Branch. (Mail) 1315 Hutchison Ave., Charlotte, N. C.

Ghosh, Bisua N.—Jr. reclamation asst., soil conservation dept., Damodor Valley Corp., Hazaribagh, India

Gonzales, Adolfo L.—Irrigation engr., Henry C. Hitch Co. (Mail) Derry, N. M.

Gray, Fred R.—Planning engr. (SCS), USDA. (Mail) P O Box 287, Weatherford, Okla.

Guiry, Peter—Asst. in parts dept., McCormick Deering Implements, Ltd. (Mail) Mason Rd., Ladner, B. C., Canada

Gustafson, M. Lee—Irrigation sales engr., Tart-Ide Corp. (Mail) 5512 1st Ave., S., Minneapolis 1, Minn.

Haas, Roger C.—Farmer, Rolla, Mo.

Haeske, Gerold A.—302 N. Jefferson Ave., Saginaw, Mich.

Haigh, William A.—Sales trainee, The Oliver Corp., 1115 Sample St., South Bend, Ind.

Hall, Garth O.—Graduate student, Michigan State College. (Mail) Box 551, Marion, Mich.

Hamilton, W. S. D.—Territory mgr., John Deere Plow Co., Ltd. (Mail) Box 19, Merrickville, Ont., Canada

Harris, Donald F.—Sales engr., Race and Race, Inc., Winter Haven, Fla. (Mail) 730 West Central

Harrison, H. P.—Zone mgr., Massey-Harris Co., Ltd., Regina, Sask., Canada

Hedlind, George—Field supervisor, Linn Co. PMA. (Mail) 352 A St., Corvallis, Ore.

Hodges, Teddy O.—Res. fellow in agr. eng., Iowa State College, Ames, Iowa

Ingersoll, James H.—Asst. to the president, Ingersoll Products Div., Borg-Warner Corp., 310 S. Michigan Ave., Chicago 4, Ill.

Jandeth, Elmer P.—Instr., veterans' farm training program, Wallace Independent School, Wallace, S. D.

Karlin, Marne J.—Co-owner, asst. mgr., Karlin Farms, Catherine, Kans.

Kepner, Carl L.—Supervising engr., Caterpillar Tractor Co. (Mail) 412 Indiana, Morton, Ill.

(Continued on page 120)

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CONSTRUCTION
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RILCO
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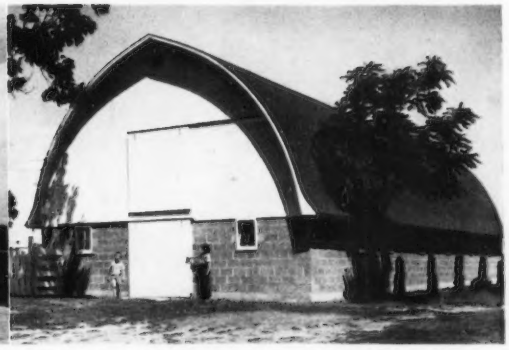

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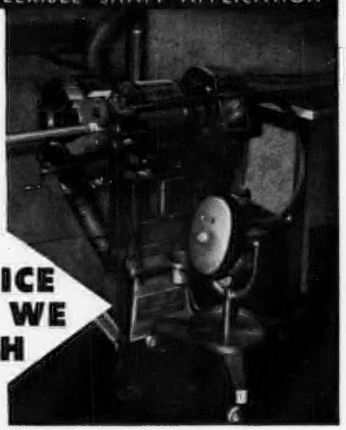

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APPLICANTS FOR MEMBERSHIP

(Continued from page 118)

Kinnear, Robert B.—Agr. engr. (SCS), USDA. (Mail) 421½ Defiance Ave., Findlay, Ohio

Kolega, John J.—Graduate fellow in agr. engr., Oklahoma A. and M. College, Stillwater, Okla. (Mail) Bennett Hall, E469

Lane, John M., Jr.—Housing engr., Maine Agricultural Extension Service, Orono, Me. (Mail) Agricultural Engineering Bldg.

Lauderdale, Lawrence A.—Agr. engr., Benton-Lincoln Electric Co-op., Inc., Corvallis, Ore. (Mail) 3507 Tyler St.

Lipp, Harold C.—Agr. engr., National Farm Machinery Co., Ohio Cultivator Div., Bellevue, Ohio. (Mail) 316 Northwest St.

Magee, Robert M.—Territory mgr., John Deere Plow Co. (Mail) 17489 Via Alamitos, San Lorenzo, Calif.

Marston, Richard H.—Agr. engr. (SCS), USDA. (Mail) 558 Plymouth St., Whitman, Mass.

Matthews, James S.—Agr. engr. (SCS), USDA. (Mail) Berlin, Okla.

McDougall, Wallace—Jr. proj. engr., New Idea Div., Avco Mfg. Co., Coldwater, Ohio

Meyer, Calvin J.—Owanka, S. Dak.

Myers, Edward G.—Safety inspector, safety dept., Milan Arsenal, Milan, Tenn. (Mail) 316 W. Main St.

Myers, Jimmy D.—Trainee, Caterpillar Tractor Co., Peoria, Ill. (Mail) Training Dept.

Nelson, Dwight F.—Sales engr., Masonite Corp. (Mail) R R 2, Boone, Iowa

Palmer, Wayne B.—Salesman, International Harvester Co. (Mail) 316 S. Henry St., Madison, Wis.

Patterson, Robert K.—Inst. in agr. eng., University of Massachusetts, Amherst, Mass. (Mail) Engineering Annex

Raulin, Glenn J.—Agr. engr., Swan Road, Centredale, R. I.

Riekman, W. L.—Field engr., Massey-Harris Co., Ltd. (Mail) Apt. 10, 1570 King St., W., Toronto, Ont., Canada

Rigney, James C.—Agr. engr., exp. lab., Allis-Chalmers Mfg. Co. (Mail) 819 N. 34th St., Milwaukee 8, Wis.

Roden, Darrell O.—Asst. foreman, United States Sugar Corp., Clewiston, Fla. (Mail) Box 7330

Schlegel, Wallace A.—43rd Div. Band, Camp Pickett, Va.

Schriml, A. L.—Eng. rep., Dayton Rubber Co., 1009 N. Washington Blvd., Chicago 7, Ill.

Scott, V. H.—Asst. prof. of irrigation eng., irrigation div., University of California, Davis, Calif.

Smallshaw, J. W.—Trainee, Chain Belt Co. (Mail) 3614 N. 14th St., Milwaukee 13, Wis.

Smith, L. A.—Sales and development, Aluminum Co. of Canada, Ltd., 1700 Sun Life Bldg., Montreal, Quebec, Canada

Smith, Robert K.—Ext. spec. in rural elecn., Mississippi Agricultural Extension Service, State College, Miss.

Stanton, Harold S.—Instr. in agr. eng., University of Arkansas, Fayetteville, Ark.

Schneider, Jay N.—Farmer, Box 254, R R 2, Kokomo, Ind.

Sowers, Lee R.—Conservation aide, Mills Co. Soil Conservation District. (Mail) Henderson, Iowa

Storm, Donald P.—Trainee, Skelgas Div., Skelly Oil Co., Kansas City, Mo. (Mail) 3716 Garfield

Wenker, Harold E., Jr.—Factory rep., F. E. Myers and Bro. Co. (Mail) 866 Liberty St., Meadville, Pa.

Williams, Herbert J.—Farm engr., Colorado Central Power Co., 3470 S. Broadway, Englewood, Colo.

Williams, James M., Jr.—Instr. in agr. eng., North Carolina State College, Box 5906, College Station, Raleigh, N. C.

Winter, Dean W.—Res. asst. in agr. eng., University of Illinois, Urbana, Ill. (Mail) 216 Agricultural Engineering Bldg.

Witherspoon, D. F.—Graduate student in agr. eng., Michigan State College, East Lansing, Mich. (Mail) 208 West Shaw Hall

Zehner, William H.—Chief des. engr., F. E. Meyers and Bro. Co., Ashland, Ohio

TRANSFERS OF MEMBERSHIP GRADE

Bryce, George E.—Agr. eng. spec., ext. service, Manitoba Dept. of Agriculture, 153 Legislative Bldgs., Winnipeg, Manitoba, Canada (Associate Member to Member)

Christopherson, C. H.—Assoc. prof. of agr. eng., University of Minnesota. (Mail) 2279 Commonwealth Ave., St. Paul 8, Minn. (Affiliate to Member)

Crawford, Paul A. Jr.—Rural elecn. spec., Georgia Agricultural Extension Service, Athens, Ga. (Associate Member to Member)

Holekamp, Emmett R.—Instr. in agr. eng., University of Arizona. (Mail) 448 University Ave., Davis, Calif. (Associate Member to Member)

Rokeby, Thomas R. C.—Graduate asst. in agr. eng. res., Ontario Agricultural College, Guelph, Ont., Canada (Affiliate to Associate Member)

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by modernizing with Jamesway!

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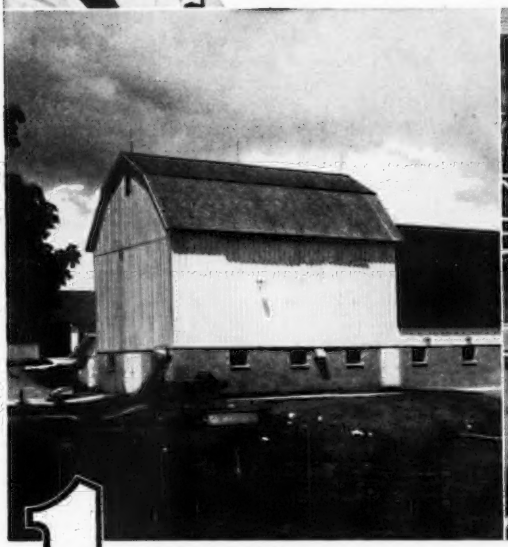

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SPRAY NOZZLES

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..best performance

Internal design of the nozzle, one of the most complex in hydraulic engineering plus precision in machining . . . these are the two major elements that determine nozzle performance. With **TeeJet** Spray Nozzles you can be sure of engineering at its best and manufacture maintained at precision standards. **TeeJets** are the product of America's leading exclusive manufacturer of spray nozzles and related equipment for farm and industry.

TRIGGER TeeJet . .

The precision made trigger hand valve for portable sprayers. Available with straight or curved extensions, with fixed-type or swivel nozzle bodies. Weighs only 10½ ounces. Valve seat assembly replaceable.

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Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this bulletin the following listings still current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated:

POSITIONS OPEN: AUGUST—O-25-503, 25-504. OCTOBER—O-75-507, O-76-508, O-46-509. NOVEMBER—O-102-510. DECEMBER—O-113-514. 1951—JANUARY—O-141-515.

POSITIONS WANTED: AUGUST—W-4-2. SEPTEMBER—W-40-10. OCTOBER—W-69-13, 73-14, 71-15. NOVEMBER—W-93-16, 72-17, 99-18. DECEMBER—W-81-21, 114-22. 1951—JANUARY—W-106-24, 140-25, 135-26, 145-27.

NEW POSITIONS OPEN

EXECUTIVE for special assignments to generally assist owner-operator of a 10,000 acre plantation in the South, devoted to special crop and livestock production and processing. Requires experience in construction, engineering, agricultural and timber operations. Salary open. O-158-516

DESIGN ENGINEER for development work on tillage, planting, and cultivating implements in Midwestern plant of a full-line manufacturer. BS deg in agricultural or mechanical engineering and two or more years of experience in implement or similar mechanical design. Farm background and usual personal qualifications for commercial design. Salary open. O-168-517

AGRICULTURAL ENGINEER (assistant or associate) for research in power and machinery, chiefly development of special machines for Hawaiian crop conditions; possibly limited teaching. MS deg in engineering or equivalent; thorough understanding of machine design. Must be able to cooperate with other organizations, and have usual personal qualifications for college and research work. Faculty housing available on campus. Salary $4000 up. Additional annual bonus of $576 has been paid for several years. O-173-518

AGRICULTURAL ENGINEER for design and development work on prefabricated farm buildings and component items, with manufacturer in the Midwest. BS deg in agricultural engineering, or equivalent. Farm background and some construction or architectural experience desirable. Good cooperator with aptitude for commercial development engineering. Good opportunity for advancement. Company is expanding operations. Manufacturing division produces prefabricated items for trade area of four states. Age 25-30. Salary open. O-150-19

SALES REPRESENTATIVE for setting up and servicing dealers in prefabricated farm building items in Nebraska, Iowa, Missouri, and Kansas for manufacturer in that area. Architectural and agricultural training. Farm background and some experience in construction and sales work desirable. Pleasing personality and ability to meet people. Good opportunity for man who can adequately represent the company. Age 25-30. Salary open. Bonus arrangement. Company furnishes car. O-150-20

NEW POSITIONS WANTED

DESIGN, development, research, teaching, or sales in farm structures field, in public service or industry, anywhere in U.S.A. BS deg in agricultural engineering, 1949, Michigan State College. Graduate study in architectural engineering, one year, Clemson College. Ford parts salesman, 4 years. Clerical work 2 years. Farm hand 2 summers. Graduate teaching assistant, M.S.C., one quarter. AAF instructor in celestial navigation and dead reckoning, 2½ years. War enlisted and commissioned service in Infantry and Air Force, nearly 5 years. Married. Age 35. No disability. Available now. Salary open. W-147-28

DESIGN, development, research, or teaching in power and machinery with industry or public service, anywhere in continental U.S.A. or Hawaii. BS deg in agricultural engineering, 1949, University of Idaho. MS deg in agricultural engineering, 1950, University of Minnesota. Irrigated farm background. Prewar business experience as bookkeeper, typist, and factory storekeeper. War enlisted service over 3 years in Medical Corps, Army Specialized Training Program, and Signal Corps. Summer 1947, recorder, U.S. Geological Survey triangulation party. Summer, 1948, assistant to educational director of farm equipment wholesaler. Past 1½ years research assistant, University of Minnesota, on machines for applying herbicides and on flame cultivation of corn. Single. Age 27. Vision corrected with glasses. Available May 15. Salary $4000. W-148-29

DESIGN, development, research, or writing, in power and machinery field, with manufacturer or federal agency, anywhere in U.S.A. or in Europe or South America. BS deg in agriculture, major in agricultural engineering, January 1951, University of Connecticut. Farm background. Part time student work in agricultural engineering department. Experience in building trade. War enlisted service in Navy, 3 years, machinist mate. Married. Age 28. No disability. Available now. Salary open. W-151-30

TEACHING or research in farm structures or soil and water field with college, experimental station or manufacturer, anywhere in U.S.A., Midwest preferred. BS deg, 1949, MS deg expected June 1951, both in agricultural engineering, University of Missouri. Farm background. Part time teaching in farm shop and elementary water management at University of Missouri, September 1949 to present. Research during same period on farm pond water for domestic use. War noncommissioned service in Infantry nearly 2 years. Married. Age 25. No disability. Available June 15 or September 1. Salary open. W-156-31

(Continued on page 124)

Nature's Warning of what's to come..

When the small furrows of sheet erosion show, it's high time a conservation program be put to work! Even though it may take a good many heavy downpours to highlight the damaging effects, each rain takes its toll of top soil.

Conservation is good business anytime. Using land to its best advantage — rotating crops, leaving grassed waterways, contouring, strip-cropping, building ponds, planting marginal sections to grass and timber — helps insure a more prosperous agriculture. It pays off in terms of easier farming and higher yielding crops . . . and at the same time, helps preserve productive land for the generations to come.

If we're to save our dwindling supply of rich top soil, we must work together. Conservation demands teamwork. Saving our soil is a job for all of us — for we who design and build farm machinery . . . for the farmers who use it . . . and for you, the agricultural specialists, who work with and guide our 6 million farmers.

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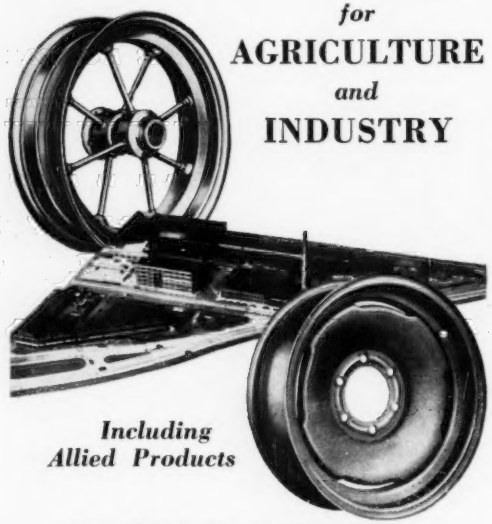

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This position is with one of Chicago's best known advertising agencies. It provides the opportunity to write national and local farm paper advertising — to develop complete promotional campaigns — to prepare interesting mailing and catalog pieces. Previous advertising agency experience is not necessary, but would be a distinct asset. A first-hand familiarity with Western or Southern farming would also be helpful. Write us about yourself, giving full details of your training and experience and enclosing samples of your work.

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RATES: Announcements under the heading "Professional Directory" in AGRICULTURAL ENGINEERING will be inserted at the flat rate of $1.00 per line per issue; 50 cents per line to A.S.A.E. members. Minimum charge, four-line basis. Uniform style setup. Copy must be received by first of month of publication.

PERSONNEL SERVICE BULLETIN

(Continued from page 122)

SALES, or service in rural electric field, including pump installations and service, electrical appliance work, or work with rural electric cooperatives. Industry or public service, preferably in Southwest or Rocky Mountain area. BS deg in agricultural engineering, January 1951, New Mexico College of Agriculture. Western Electric Co., 11 months. Summer 1950, chief supervisor, Dona Ana office of Production and Marketing Administration. War enlisted service in Navy 1½ years, radar man 3/C. Single. Age 23. No disability, available now. Salary $2900-$3100. W-152-32

DESIGN, development, or research in power and machinery, with industry or public service, anywhere in the U.S.A. BS and MS degs in agricultural engineering, 1948 and 1949, University of Illinois. Research on spray equipment June 1948 to August 1949. Teaching power and machinery courses since September 1949 at University of Missouri. War enlisted service in Navy, 2 years. Married. Age 24. No disability. Available July. Salary $4000-4500. W-162-33

DESIGN and development in power and machinery, with manufacturer, anywhere in the U.S.A. BS deg in agriculture plus 2 years graduate work in farm power and machinery. Farm background. Experience, 10 years in design and testing of harvesting, tillage, and planting machinery. Soil conservation and forestry work 3 years. Able to direct farm equipment development program. Married. Age 40. No disability. Available July. Salary open. W-163-34

SALES, service, or engineering in farm power and machinery field, with manufacturer, anywhere in the U.S.A. BS deg in agricultural engineering, 1950, Pennsylvania State College. Experience 4 months servicing heavy earthmoving equipment such as diesel tractors, power shovels, trucks, air compressors, rollers, pumps and power units. Cable splicer, Bell Telephone Co. of Pennsylvania, 5 years. Summer work at Pennsylvania State College as general farmhand at bull calf research barns. Recorder on sheet steel in process, J. and L. Steel Co., Pittsburgh. Electrician's helper on home wiring and general electrical work. War enlisted and commissioned service in Navy, 3 years. Age 29. No disability. Available on reasonable notice. Salary open. W-164-35

Water for Manufacturing

(Continued from page 83)

7 per cent indicated that an unlimited number of additional plants were possible. From the Chicago area, 147 replies ran the full range of opinion, with 56 per cent claiming no knowledge as to future possibilities. Even in the metropolitan area of New York, with its widely publicized water shortage, 60 per cent did not know, while 9 per cent said the water potentialities were adequate for a large number of additional plants.

As to pollution, the divergence of opinion is equally wide. For the Chicago area, for example, 13 per cent of 132 replies said that pollution is serious while 32 per cent said it is practically non-existent. Also for the Chicago area 37 per cent of 130 replies said the pollution situation is improving, while 12 per cent said it is growing worse. This corresponds quite closely to the indicated nation-wide divergence of opinion as to the status and trend of pollution.

These differences of opinion may be accounted for in part by actual differences in the situation at the various plant locations within individual areas. It seems significant, however, that over the country as a whole, 39 per cent of replies, the largest single group, from over 3000 plants, claimed no knowledge as to potentialities for expansion of water use in their respective areas.

This matter of water supply for manufacturing industries is related to agricultural water supply as there is and must be interflow of water, products, and money between agricultural and manufacturing areas. Above all else, the survey report suggests the extent of our need for more factual and widespread information on our water resources.

Increasing appreciation of the problem and support of constructive work in this direction, by manufacturers, should prove a strong stimulus to progress.

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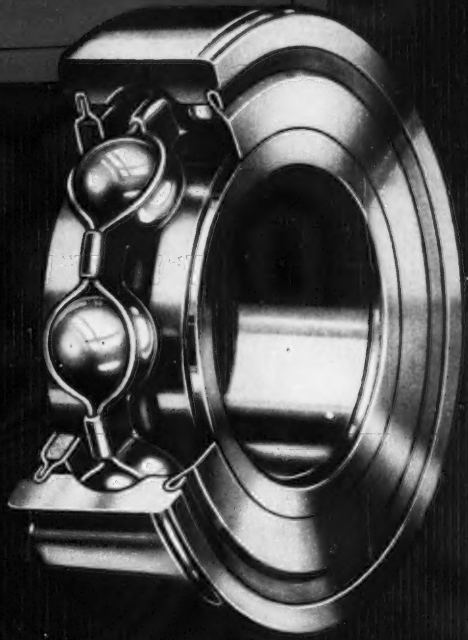
The concept of
cutting maintenance
and increasing life
in mechanisms
by new bearing design
originated with
New Departure



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ball bearing. Ask for it.

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124

Design Perfection IN FORAGE HARVESTERS

FORAGE HARVESTER MOUNTINGS

FEATURING TIMKEN® BEARINGS ON THE CUTTER KNIFE SHAFT

Used in the field to harvest and cut all types of forage---from ordinary timothy, alfalfa or mixed hay to heavier types such as corn silage---the forage harvester has saved farmers a tremendous amount of labor.

In the design perfected by The Fox River Tractor Company, the cutter knife shaft features the indirect mounting of single-row Timken tapered roller bearings. As shown in the illustration, the right hand Timken bearing is held in place by means of a sleeve shrunk on the shaft. The left hand Timken bearing set-up is locked in place by using a sleeve, nut and tongued washer. Seals are designed for grease lubrication.

This is another example of how leading manufacturers in the farm implement industry are using Timken bearings in their designs. To obtain illustrations of typical bearing mountings for all types of farm equipment and machinery, be sure to write for your free copy of the Farm Equipment Section to our Engineering Journal.

THE TIMKEN ROLLER BEARING COMPANY
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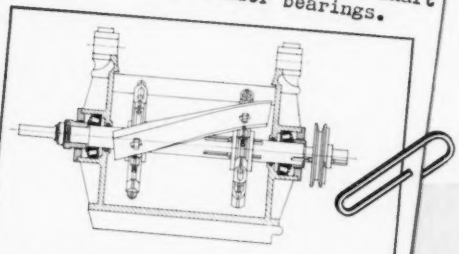

How Timken bearings are used on the cutter knife shaft of the Fox Forage Harvester manufactured by The Fox River Tractor Company, Appleton, Wisconsin.

Tapered Roller TIMKEN BEARING EQUIPPED

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